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TECHNICAL MANUAL

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SWIMMING POOL OPERATION AND MAINTENANCE

HEADQUARTERS, DEPARTMENT OF THE ARMY
28 FEBRUARY 1986

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HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, DC, *28 February 1986*

REPAIRS AND UTILITIES
SWIMMING POOL
OPERATION AND MAINTENANCE

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CHAPTER 1

INTRODUCTION

1-1. PURPOSE.

This manual provides guidance for the effective operation and maintenance of swimming pools and associated equipment at Army Installations by personnel assigned to the Directorate of Engineering and Housing organization. It may be used as a general reference source in related training programs. This manual does not replace nor modify manufacturers' instructions on specific equipment. Objectives are to achieve sanitary and efficient operation and maintenance of swimming pools and to eliminate hazards to life and property.

1-2. REFERENCES.

Appendix A contains a list of references used in this document.

1-3. APPLICATIONS.

This manual describes, and provides guidance relating to,

a. The various type of swimming, wading, and spray pools at Army installations.

b. The operation and maintenance of:

(1) Swimming and wading pools.
(2) Water treatment facilities.
(3) Piping system components.
(4) Water heating equipment.
(5) Ventilation and dehumidifying equipment.
(6) Safety equipment.
(7) Electrical wiring, lights, and equipment.

c. Management of Pools and Equipment.

d. Observance of water quality standards and tests in accordance with TB MED 575.

1-4. MORALE.

Swimming is one of the best forms of exercise for improving muscle tone and body coordination, and it is also an excellent means of recreation. For these reasons and the fact that the lives of military personnel may sometimes depend on their ability to swim, swimming is strongly encouraged.

1-5. HEALTH.

Although there is little evidence that swimming pools present a significant health hazard, disease can be spread by contaminated swimming pool water or by contact with contaminated objects or persons in the pool or pool area. Some of the illnesses known to be spread by contaminated water are: colds and respiratory infections, typhoid fever, amoebic and bacilary dysentary, cholera, diarrhea, hookworm, tapeworm, infectious hepatitis, intestinal disorders, and miscellaneous eye, ear, nose, throat, and skin infections. Therefore, it is highly important to eliminate organisms which cause these diseases from swimming pool water.

1-6. ENERGY CONSERVATION POLICY.

All military swimming pool installations should have a management improvement program that includes policies and guidelines relating to the efficient use and conservation of utilities. Such programs are offered by the National Swimming Pool Institute and various swimming pool manufacturers. Conservation measures should be implemented by supervisory, operating, and maintenance personnel. The importance of using, adjusting, and maintaining equipment properly cannot be overemphasized.

CHAPTER 2

SAFETY

2-1. GENERAL.

Most military installations have swimming pools. The benefits derived from swimming and the safety associated with it depend on how these pools are operated.

2-2. OPERATING SUGGESTIONS.

A swimming pool can be both safe and enjoyable if proper supervision of bathers and proper maintenance of the pool facilities are accomplished. Safe operation suggestions, such as the following, can provide the responsible swimming pool operator a basis for preventing serious injury or for treating accidents rapidly:

a. Keep crystal clear water in the pool.

b. Employ well trained and alert guards to prevent minor injuries and drownings.

c. Maintain rescue equipment such as hook poles and life preservers at all times.

d. Have a telephone installed in a prominent location, along with a list of telephone numbers of emergency medical and or rescue facilities available at the installation. The list should be protected adequately against defacement from weathering, vandalism, and other normal causes.

e. Limit number of bathers using pool to that prescribed in paragraph 3-8, TB MED 575.

2-3. DANGEROUS PRACTICES.

a. Signs prohibiting the following dangerous practices should be posted in the pool area:

(1) Swimming alone or without supervision.

(2) Entering pool soon after eating (the larger the meal, the longer interval before safe swimming).

(3) Overexposure to sun or water.

(4) Boisterous conduct such as running, shoving, throwing others into pool, or attempting feats beyond skill or endurance.

(5) Diving in shallow water or bounding on diving board.

(6) Tag and follow-the leader games.

(7) Swimming during thunderstorms (lightning danger).

b. Swimming pool operators can eliminate many of the above dangerous practices through alert supervision of the pool area. (Suggestion: Provide instruction periods and organized aquatic programs.) Other dangerous practices, such as inexperienced persons tampering with equipment and lifeguards engaging in unnecessary conversation, should also be closely supervised. (Suggestion: Many pools would benefit by giving the lifeguards more responsibility and authority to control bathers.)

2-4. POOL DESIGN.

For pool design parameters see TB MED 575.

2-5. POOL DEPTH.

The water depth should be marked plainly at or above the water surface on the vertical pool wall and on the edge of the deck next to the pool. The points of maximum and minimum depth, the points of break between the deep and shallow ends, and intermediate 1-foot increments of depth should be marked. Intervals between depth markings should not be more than 25 feet; numerals should be 4 inches minimum height and of a contrasting color. The outlet of the pool should also be marked plainly in an appropriate contrasting color.

2-6. POOL ACCESSORIES.

Diving boards, diving platforms, and ladders to slides should be rigidly constructed, should have nonslip surfaces, and should be properly anchored to insure stability under the greatest possible load. At least 15 feet of unobstructed headroom should be provided above all diving boards and platforms. A horizontal separation of at least 10 feet should be provided between diving boards and sidewalls (this may be reduced to 8 feet for surface boards). The maximum safe elevation of diving boards and platforms above the surface of the water in relation to the depth of the water is given in the following table:

Height of board or platform (feet)	*Minimum water depth at end of board and 12 feet beyond (feet)*	*Minimum pool width at end of board and 12 feet beyond (feet)*
0-6	8.5	20
6-9	10.0	30
>9	11.5	30

2-7. WATER CLARITY.

Clarity of water should be maintained at all times during the pool season, not only for attractiveness, but also as an indication of proper equipment functioning and as an accident prevention means. A black disk 6 inches in diameter on a white field, when placed on the

bottom in the deepest point of the pool, should be clearly visible from the sidewalks of the pool at all distances up to 10 yards, measured from a line across the pool through the disk. This minimum standard should easily be met by modern filtration systems.

2-8. POOL COLORS.

One of the outstanding assets of any pool is its clear, sparkling water and this is displayed best by having the pool walls and bottom of a light color. Light colors also improve visibility. White, light blue, and aqua blue are frequently used with excellent results. Alternately, dark colors absorb light, restrict vision, obscure dirt deposits, and tend to make maintenance personnel lax in removing sediment.

2-9. POOL LININGS.

For design information on pool linings refer to TB MED 575.

2-10. POOL LIGHTING.

Proper pool lighting not only enhances the appearance of the pool area, but also provides necessary illumination for safety. Arrangement and design of lighting should be such that all surface and bottom areas of the pool, springboards, towers, floors, and other appurtenances are clearly visible to the lifeguards. Lights within sidewalls must be protected and recessed to prevent tampering or breakage. Underwater lights must be grounded and installed so as to prevent hazards to bathers. Electrical safety requirements are stated in article 680 of the 1981 National Electrical Code and have been made more stringent than previous requirements. Therefore, pool facilities constructed prior to this may not meet minimum electrical safety standards. Underwater lighting and electrical outlets in the pool area should be examined to insure that they comply with current requirements for ground fault protection and distance (clearance). In general, it is good practice to remove all unnecessary electrical equipment in the pool area and maintain the essential equipment in accordance with the National Electrical Code.

2-11. ACCIDENT PREVENTION.

Accidents and drowning deaths are the most serious problems in the control of swimming pools. Lack of effective bather supervision, poor construction, and improper operation and maintenance of equipment are prime causes of such casualties. A regular routine should be established for daily inspection of the pool area and all pool equipment. The cracking or flaking of concrete can be hazardous to bathers and should be repaired as soon as possible. Pool ladders, diving board supports, diving towers, and lifeguard chairs should be periodically checked to assure that they are firmly anchored and in good condition. Ladders and diving equipment should be inspected for the presence of any foreign matter which would render them slippery. After maintenance of moving parts or electrical connections in the equipment room, a safety check should be made to assure that all safety guards and electrical box covers are replaced and valves are properly tagged and positioned. Electrical circuits should be deenergized before working on any equipment. Where wet, slick, or other conditions contribute to slippery walking surfaces and consequent hazards to personnel, nonslip surface treatments should be applied.

2-12. DANGEROUS CONDITIONS.

The following dangerous conditions should be eliminated:

a. Poorly drained, slippery floors and walks.

b. Shower-valve arrangement capable of scalding (central automatic mixing valve is best).

c. Caking soap or leaking soap dispenser.

d. Abrupt changes in the slope of the pool floor or underwater steps.

e. Insufficient depth or area for diving.

f. Excessively high, shakey, or slippery diving equipment.

g. Lack of water depth markings.

h. Turbid water (the bottom at the deepest point should be easily visible from the pool edge).

i. Pool drains, outlets, or other fixtures which could hold a person underwater.

j. Electrical equipment capable of shocking (e.g., underwater light fixtures must be grounded).

k. Water slides poorly located, causing "traffic" congestion.

l. Projecting or ungrated pipes.

m. Improperly vented chlorinators.

n. Use of glass containers of any type in the pool area.

2-13. LIFESAVING FACILITIES.

Equally as important as preventing accidents is being prepared to quickly and effectively respond to an accident. Preparedness includes the following items:

a. Lifeguards: A qualified lifeguard having a valid American Red Cross Senior Certificate or equivalent should always be on duty when the pool is in use and should be positioned to observe the entire swimming area.

b. Lifesaving Equipment: Swimming pools should be furnished with the following lifesaving equipment: (a) a pole, greater in length than one-half the swimming pool width, capable of extension to all sections of the floor of the pool, constructed of suitable lightweight material and having a life hook (shepherd's crook) at the end with an aperture of at least 18

inches between the tip of the hook and the tip of the pole; (b) a "flutter board," approximately 1 foot by 3 feet by 3 inches, capable of supporting in water a weight of not less than 20 pounds; with 3/16-inch lines attached at least equal in length to the maximum width of the pool; and (d) a separate throwing rope with a length not less than one-half the maximum width of the pool. These items should be furnished on the basis of one each for every 2,000 square feet of pool surface area (see figure 2.1). Elevated lifeguard platforms or chairs should also be furnished on the basis of one per 2,000 square feet of pool area.

c. Location of Equipment: Lifesaving equipment should be conspicuously displayed and strategically located around the pool deck or at lifeguard chairs. The equipment must be readily accessible, kept in good repair, and the function of each item marked. Bathers or other unauthorized personnel must not be permitted to tamper with or use the equipment for any purpose other than its intended use.

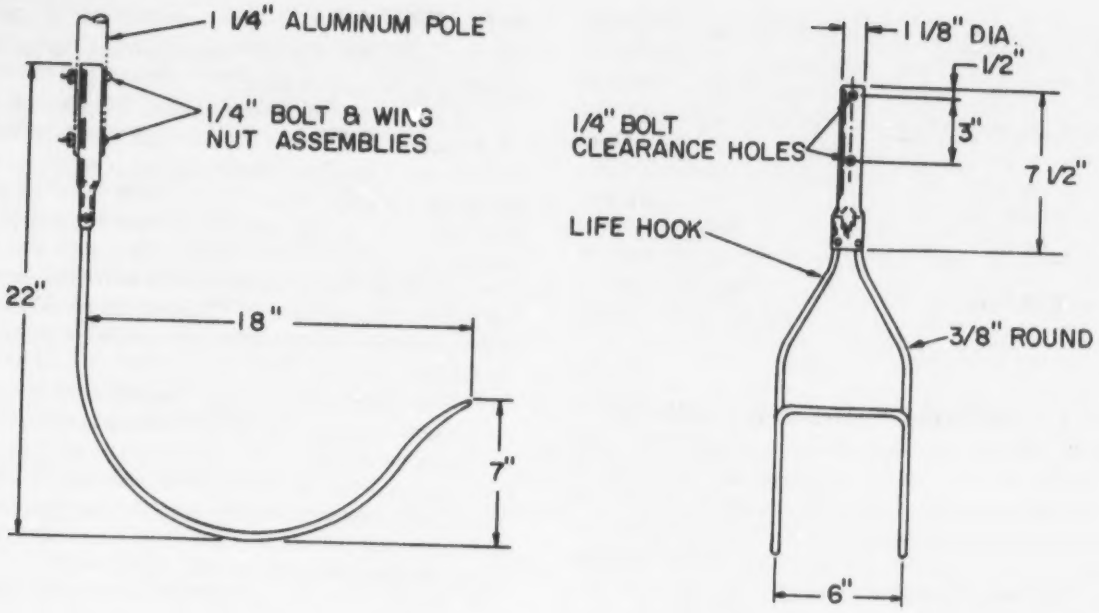
2-14. FIRST AID.

The following first aid techniques are most often used to revive drowning victims:

a. Mouth-to-Mouth Resuscitation: Mouth-to-Mouth resuscitation is the most effective and easily administered form of artificial respiration with which all pool operating personnel should be familiar. Procedures for administering mouth-to-mouth resuscitation are explained in detail and illustrated in TM 5-682.

b. Artificial Respiration: Artificial respiration by mechanical means (oxygen inhalers) is authorized only if properly trained operators are available to use the equipment.

c. CPR (Cardio-Pulmonary Resuscitation): Cardiopulmonary resuscitation is a lifesaving technique that combines mouth-to-mouth resuscitation with external cardiac compression to restore breathing and heartbeat. This technique should not be attempted unless administering personnel have been properly trained. Proper training requires annual certification.



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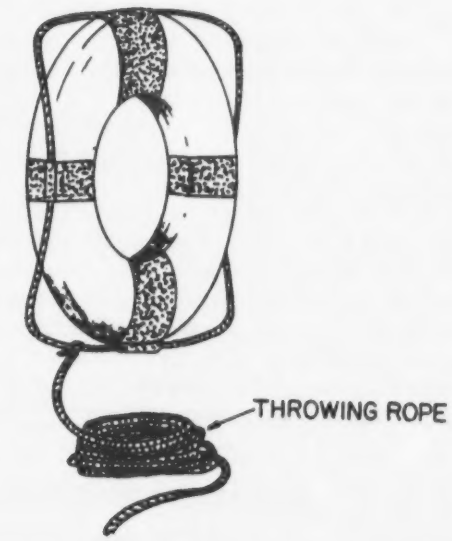


THROWING-RING BUOY

FLUTTER BOARD

Figure 2-1. Lifesaving Equipment

CHAPTER 3

TYPES OF POOLS

3-1. GENERAL.

The location, terrain, climate, source of water, and intended use determine the type of pool constructed.

3-2. FILL-AND-DRAW AND FLOW-THROUGH POOLS.

Fill-and-draw and flow-through pools which do not filter and recirculate the water are not approved for use at military installations.

3-3. RECIRCULATING POOLS.

a. Recirculating pools are pools in which the water is constantly pumped from the pool, filtered, disinfected, and pumped back into the pool. Water is added as needed to make up for losses due to evaporation, leakage, and water discharged to waste through overflow troughs. This is the most sanitary and economical type of pool and is the type approved for use at military installations. (See figures 3-1 and 3-2.)

b. The basic differences in recirculating pools, other than sizes and shapes, are in the perimeter overflow systems. The primary purpose of a pool overflow system is to provide a continuous skimming of the water surface. Overflow occurs as filtered water is added and as water is displaced by swimmers. This displaced water, containing much of the debris and other wastes, is usually returned through gutter drains to the filters; however, in some pools, the water is wasted. In some pools all the water recirculated through the filters is taken from the overflow system. In other pools, some or all of the recirculated water is taken from the main drain at the bottom of the pool. Pool overflow systems can be separated into the following three general categories:

3-4. TROUGH OR GUTTER TYPE.

Continuous gutters or troughs are constructed around the inside walls of the pool, either fully or partially recessed, or at the top of the wall in an open position (often called roll-out type gutters). (See figure 3-3.)

3-5. RIM FLOW TYPE.

This type of perimeter overflow system maintains the water at the level of the surrounding deck. No overflow troughs are used. Trenches are constructed in the deck surrounding the pool and adjacent to the pool wall. The trenches are covered with metal gratings or tile with drain openings. The deck and the pool edge are sloped toward the perimeter drains. The deck can be easily cleaned, but care should be taken that any cleaning detergents used do not cause problems such as foaming in the recirculation system. (See figure 3-3.).

3-6. SURFACE SKIMMERS.

Surface skimmers are slots constructed in the wall of the pool at regular intervals of 15 to 25 feet. Within each wall opening there are floating weirs that control the water overflow. Surface skimmers allow about 6 inches between the water level and the deck level. Each overflow weir usually discharges into a cylindrical opening that has an access cover at the deck level and a pipe at the bottom to drain the pool overflow to the recirculation system. A removable leaf-strainer basket fits in the bottom of this overflow receiver. (See figure 3-3.)

3-7. WADING POOLS.

A wading pool is a shallow pool (usually 6 to 24 inches in depth) intended for use by children. Health hazards due to contamination are much greater in children's pools than in adult pools because of the unavoidable habits of small children. Because the quantity of water is small and a considerable amount of debris is often carried into the pool, wading pools require frequent draining and cleaning. Wading pools should have a continuous flow of treated water providing a complete change of water every two hours.

3-8. TYPES OF WADING POOLS.

Wading pools, like regular swimming pools, can be classified as flow-through, fill-and-draw, or recirculation type. The newest and most sanitary type of children's pool is the spray pool. Fresh or treated water is sprayed through a nearly vertical nozzle atop a 3 to 5 foot high pipe positioned near the center of the pool. By regulating the water pressure, all the sprayed water falls into the pool. A drain at the low point of the pool continuously discharges water to waste; therefore, no water accumulates in the wading pools. The conversion of wading pools to spray pools, which is comparatively easy, is highly recommended. (See figure 3-4.)

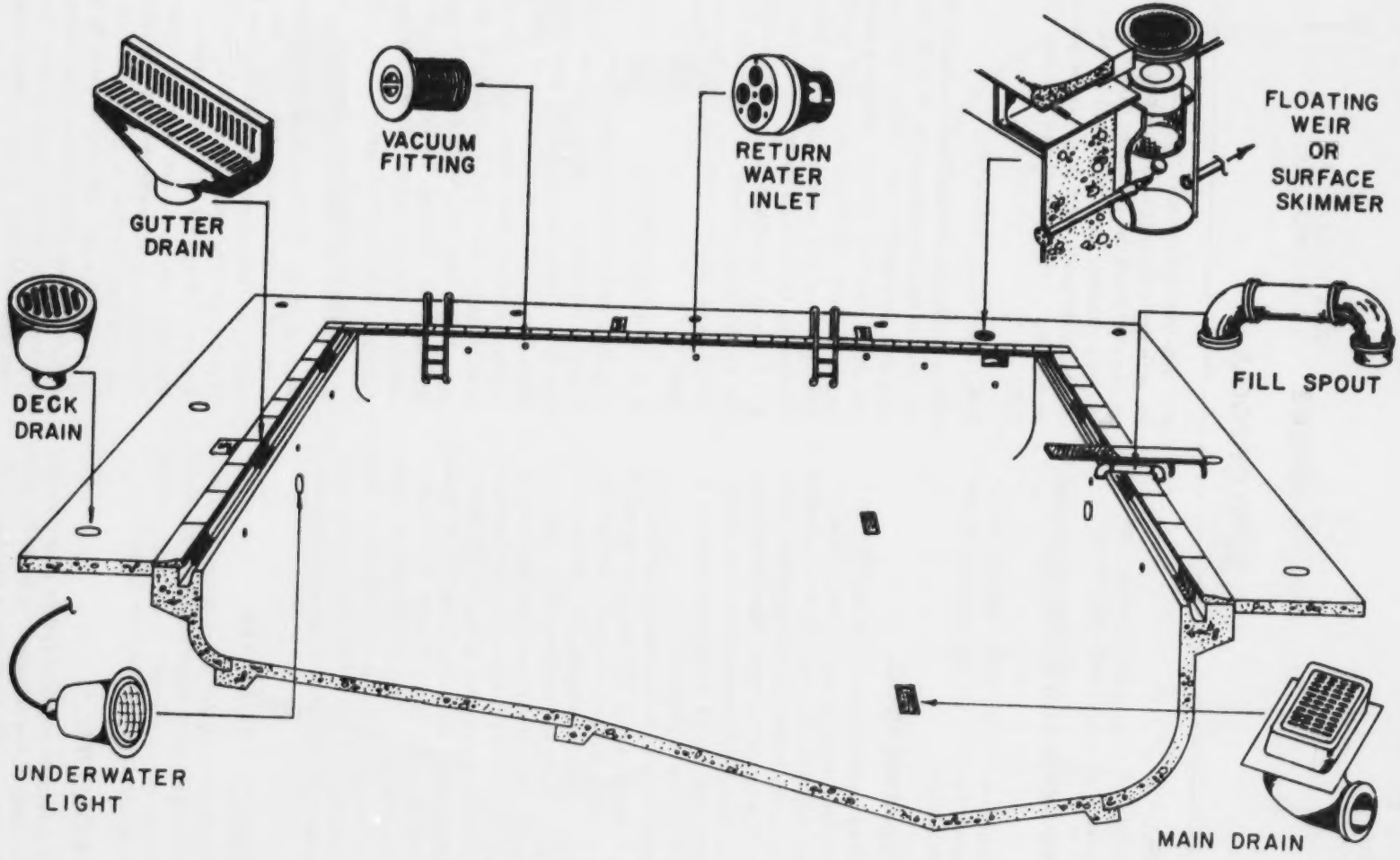


Figure 3-1. Longitudinal section through pool, showing fittings

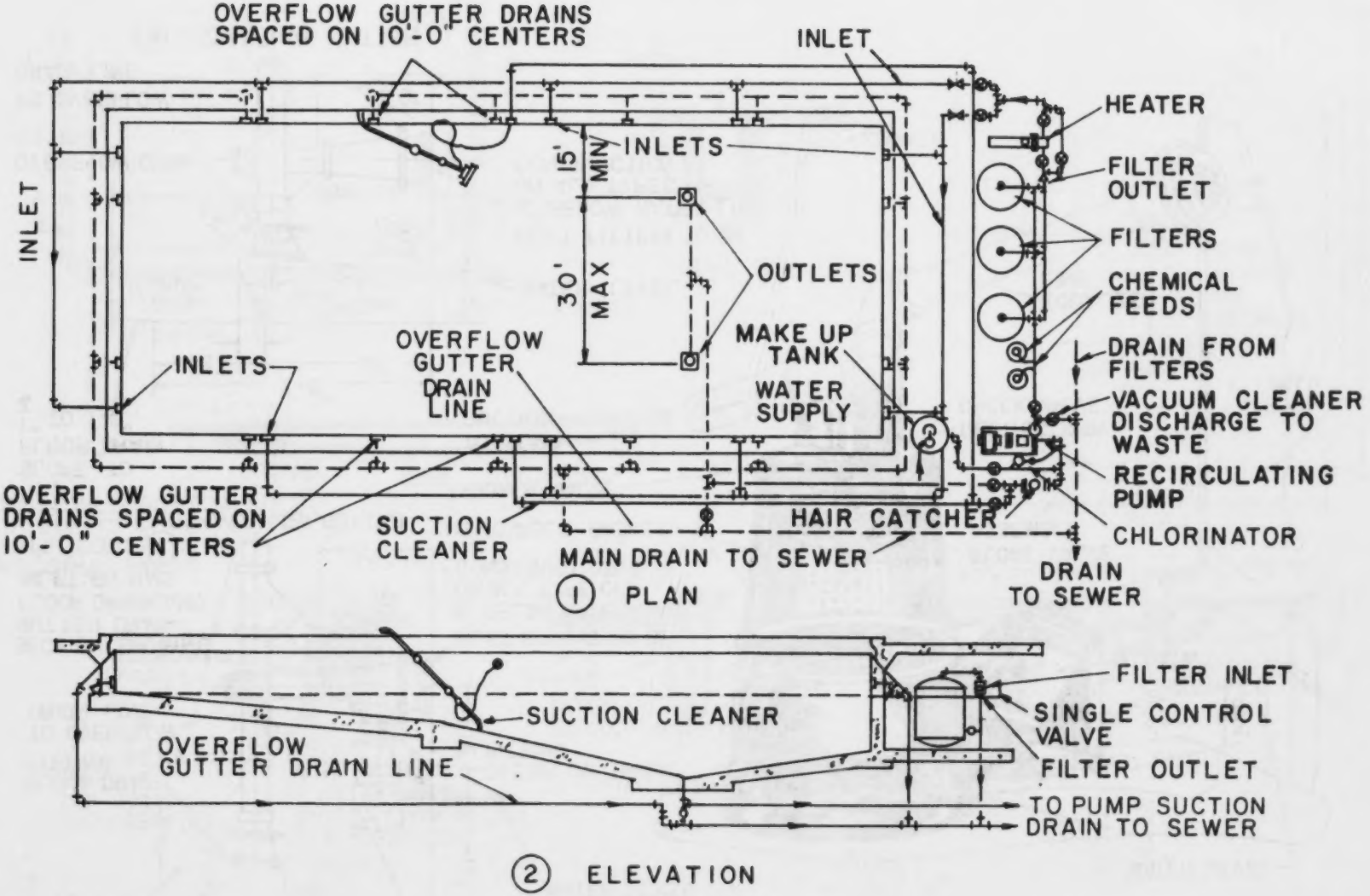


Figure 3-2. Typical recirculation pool and equipment

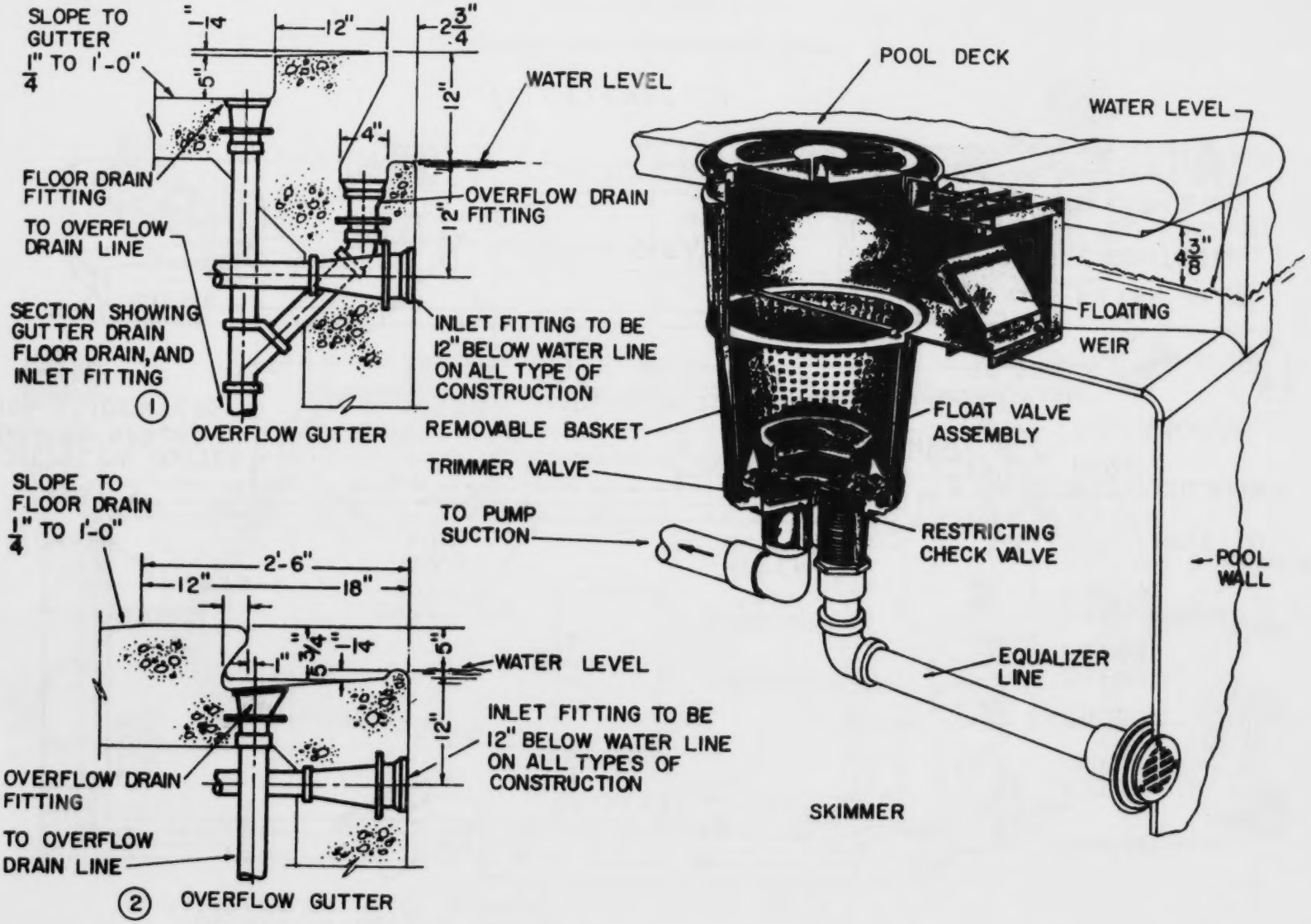


Figure 3-3. Overflow gutter and skimmer

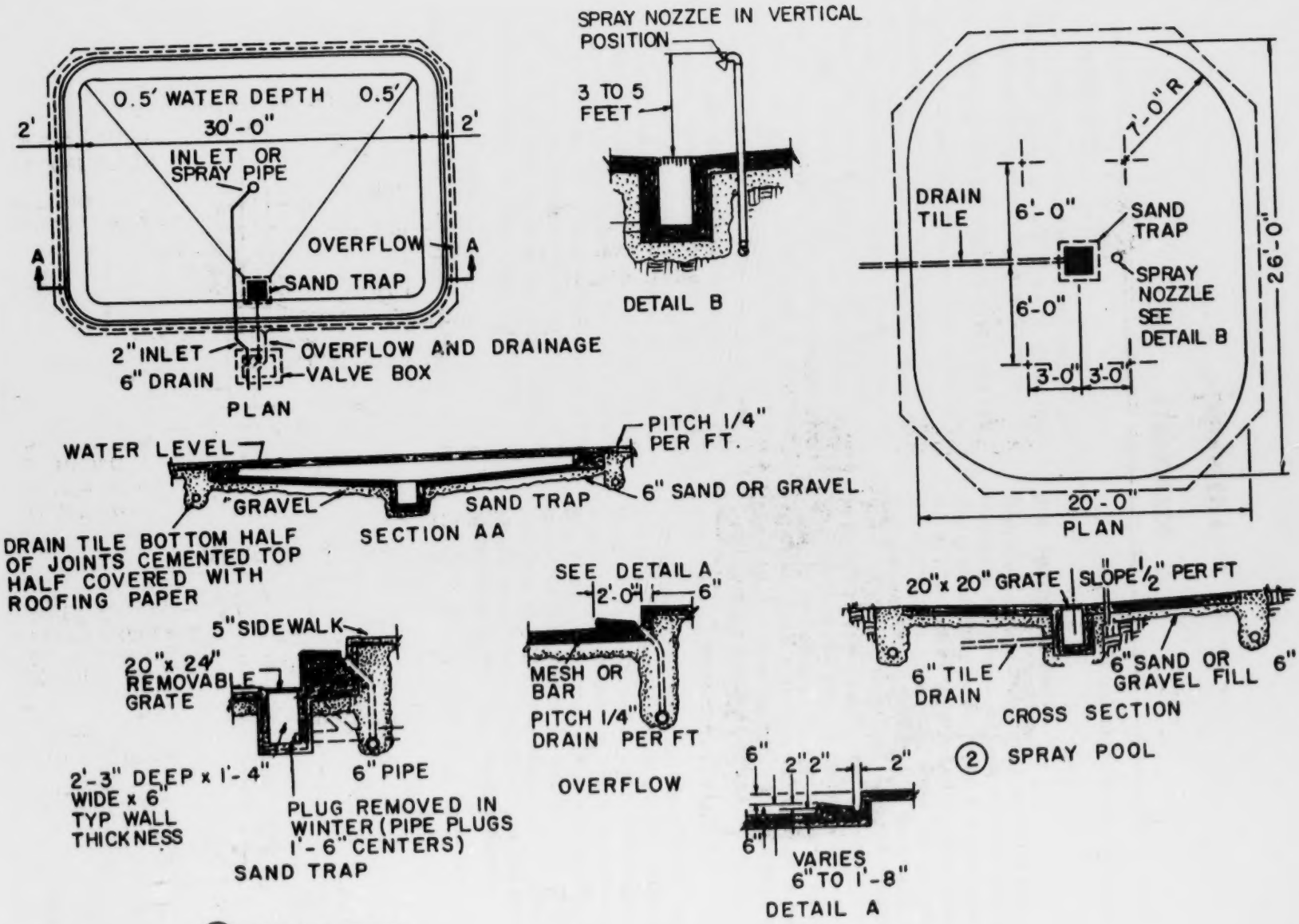


Figure 3-4. Typical children's pools

CHAPTER 4

STANDARDS

4-1. PERSONNEL.

Personnel hired to perform the various types of pool maintenance, operation, and lifeguard duties must have evidence of proper training or qualifications.

4-2. QUALITY OF SWIMMING POOL WATER.

Disinfection of swimming pool water is achieved by maintaining a bactericidal concentration of chlorine distributed uniformly throughout the pool. Methods of applying disinfectants and tests for determining residual concentrations are outlined in TB MED 575 and TM 5-660. Chlorine residuals and corresponding pH values for optimum bactericidal action and minimum eye irritations are given in Appendix B. Laboratory examinations for determining total bacteria count and numbers of the coliform group are as outlined in "Standard Methods for Examination of Water and Wastewater," latest edition. Not more than 15 percent of the samples examined during any 30-day period may contain more than 200 MPN bacteria per milliliter (ml) or not more than 15 percent of the samples may show positive (confirmed) test for coliform organisms in any of the five 10 ml portions comprising each sample. When the membrane filter procedure is used, not more than 15 percent of the membrane filters may show more than 1.0 coliform organism per 50 ml.

4-3. WORK SCHEDULE.

Work schedules are established contingent on the number of pool users and operation and maintenance duties.

4-4. HOUSEKEEPING.

High maintenance standards will insure the safe and economical operation of an entire pool area. The first step in maintaining a clean pool is to prevent foreign matter from entering the pool. Floating debris is easily disposed of by keeping water levels high enough to maintain a constant overflow into the troughs and weirs. Allowing the water level to drop prevents proper disposal of floating debris and also causes a scum ring to form around the pool. Sediment and debris deposits on the bottom of the pool should be removed daily with suction equipment and discharged to waste. Normally, it is not necessary to empty a properly operated recirculating pool for cleaning.

4-5. SANITATION.

Sand, grass, leaves, dust, and other foreign matter may be tracked into the pool by bathers or blown in by the wind. To minimize this, direct access to the pool area should be prevented by routine bathers through foot sprays or showers. Also persons wearing shoes should not be allowed on the pool deck. Pool walkways and decks must be kept thoroughly clean to maintain sanitation and prevent accidents. Cracks and low spots in the pool deck should be promptly repaired.

CHAPTER 5

PRINCIPLES OF POOL OPERATION

5-1. PATRON SANITATION.

Pool sanitation begins with bather supervision and discipline. For the most part, the rules governing good conduct and cleanliness are fairly uniform as published in various pool operations publications and as posted on walls and fences of public pools throughout the United States. Unfortunately, however, the seriousness of enforcing the rules is not stressed. Not until the pool operator understands the public health involvement can he/she fully appreciate the importance of enforcing every rule without exception.

5-2. BODILY INFECTION.

An obviously healthy patron wearing a small bandage may appear entirely harmless to an untrained bathhouse attendant. However, the bandage may be covering a common pimple or sore, that has festered with staphylcoccus bacteria. Although the highly localized infection presents no serious problem for the person afflicted, it does pose a significant health hazard if these same bacteria are washed from the infection and conveyed to other bathers.

5-3. SHOWERING AND EATING.

Much more difficult to relate to public health are the rules that require nude showers with warm water and soap and that prevent food, drink, or tobacco in the pool area. Permitting patrons to enter the pool unbathed can impair the efficiency of the disinfection system by as much as 50 percent. As indicated in discussions which follow, organic soil (usually harmless in itself) imposes a serious burden upon the chemical disinfectants and filtration system if allowed to accumulate in the pool.

5-4. WATER TREATMENT TECHNIQUES.

a. Since the contamination of swimming pool water to some extent is inevitable, water treatment techniques must be established to make the water safe for bathers. Such treatment is accomplished by the operation of three interrelated and interacting systems:

(1) A system for the recirculation and distribution of pool water.

(2) A system for feeding chemicals for disinfection and control of pH.

(3) A system for the removal of particles by filtration.

b. In this chapter these systems are discussed together to emphasize the manner in which they work together to accomplish the ultimate goal of safe, clear pool water. In subsequent chapters they are discussed individually to provide the reader with detailed knowledge of how each system performs.

5-5. RECIRCULATION.

a. The function of the swimming pool recirculation system is probably best described as a type of transportation system. Water is transferred from the pool, delivered to a station where it is filtered and chemically treated, and then returned to the pool. The round trip the water takes is described by the term "turnover." Turnover is expressed as the number of hours necessary to circulate a volume of water equal to the volume contained in the pool. Another method of expression is the number of times in 24 hours that the volume of the pool is circulated; i.e., turnover in 8 hours is a turnover of three.

b. Both in theory and practice, it has been determined that the typical public pool should be recirculated continuously at a rate equal to one turnover in each 6- to 8-hour period. The Law of Dilution as developed by Gage and Bidwell suggests that such a turnover rate will provide 95 percent to 98 percent dilution of soiled pool water with water that has been filtered and chemically treated. Gage and Bidwell's law has been largely upheld in practice, and the 6- to 8-hour turnover rate has generally become a standard for the operation of public pools.

5-6. FILTRATION.

Filtration is of some value for its capacity to remove bacteria and disease producing organisms. However, its primary function is to remove soil particles which, if not removed, would increase the need for chemical treatment and reduce the germ killing and oxidizing power of disinfection chemicals.

5-7. DISINFECTION.

a. The disinfection function is a complicated process involving rather intricate chemistry. Ideally, disinfection is accomplished by introducing a germ-killing chemical to pool water in sufficient strength to rapidly destroy bacteria. Chlorine, one of a group of chemicals referred to as "halogens," is the disinfecting agent most commonly used in public pools and is therefore used as a term of reference henceforth in this manual.

b. When chlorine is added to pool water, it combines chemically with the oxygen and hydrogen components of water to produce hypochlorous acid (HOCL) which attacks and kills bacteria.

c. Disinfection may also be accomplished with bromine and the chemistry involved is much the same. The chemical reaction produces a mild acid with germ killing properties approximately equal to those of hypochlorous acid.

d. Regardless of the disinfecting agent used, the primary goal is the same: to provide a uniformly distributed disinfection and oxidation residual of sufficient strength to rapidly destroy disease producing organisms in pool water.

e. Although chlorination is primarily for disinfection to kill microorganisms, it serves another very important and useful purpose. The commonly used chlorine and bromine products possess strong oxidizing properties which cause them to react with and destroy many foreign materials other than bacteria. Many of these materials, if not destroyed by oxidation, would impart undesirable characteristics to the water such as turbidity, color or odor. This chemical destruction of foreign material plays an important part in the filtration/disinfection process, as is discussed in chapter 6.

5-8. pH CONTROL.

a. pH is a chemical abbreviation used to describe the presence of the hydrogen ion in water. Although somewhat inaccurate, pH is often explained as a measure of the relative acidity or alkalinity of water.

b. pH is measured on a scale of 0 to 14. The midpoint, 7 is said to be precisely neutral, above which alkalinity becomes progressively greater, and below which acidity becomes progressively greater. In swimming pool water it is important to maintain a slightly alkaline condition between 7.2 and 7.8. Problems develop when this range is exceeded on either side. A high pH, for example, can cause precipitation of dissolved minerals such as calcium and iron with resulting discoloration and turbidity. Low pH can cause serious corrosive damage to metals in the recirculation system. Both high and low pH will cause eye irritation.

c. From a public health viewpoint, the most serious effect of improper pH control is the reduced efficiency of the disinfection process. As pH rises above 8.0, chlorine reactions tend to produce an abundance of hypochlorite ion (OCL) rather than the desired hypochlorous acid (HOCL) greatly reducing germ-killing oxidizing powers. Sections 6.5 discusses a procedure of super chlorination that can be successfully used with high chlorine values and high pH under careful control. Also "breakpoint" chlorination, which is covered in paragraph 6.6, is effective in burning out the ammonia content of the pool water. As the pH value rises the chlorine residual progressively weakens. A pH value above 8.5 makes the chlorine virtually useless for disinfection and oxidation purposes.

d. The inexperienced pool operator is often surprised to discover that serious water problems have developed despite the fact that filters are functioning properly and chlorine residual reads strong in the chlorine test procedure. In such cases, the problem is often traced to the fact that pH has been permitted to drift well into the undesirable zone above 8.0 or below 6.8.

5-9. ECONOMY.

Money, materials, and water can be wasted if good economy is not practiced in pool operation. Pool equipment must be maintained to prevent frequent replacement of major items. Daily pool operations must be carefully controlled to prevent the waste of chemicals, manpower, and other items. If poor operation results in contaminated water, it may be necessary to drain the pool, thereby wasting thousands of gallons of water and placing the pool out of use for some time. Routine maintenance will often prevent expensive repairs to equipment, structures, and facilities.

CHAPTER 6

THE CHEMISTRY OF CHLORINATION

6-1. HYPOCHLOROUS ACID (HOCL) FORMATION.

a. Swimming pool water is chlorinated for two important reasons:

(1) Disinfection: To kill bacteria and disease producing microorganisms.

(2) Oxidation: To react with and destroy and other contaminants such as algae, body oil, minerals, dust, and other materials which cause color, odor and turbidity.

b. To accomplish disinfection and oxidation, a chemical reaction between chlorine and water (hydrolysis) must occur to form hypochlorous acid (HOCL). Regardless of the chlorine source material used, the desired end product is hypochlorous acid, the chemical agent which destroys bacteria and other undesirable contaminants in pool water. Chlorination should occur after the water has left the equipment.

6-2. EFFECT OF pH.

Mixing chlorine and water does not necessarily produce hypochlorous acid. The pH of the water being treated determines whether the hydrolysis reaction produces an abundance of the desired hypochlorous acid or whether the primary product is hypochlorite ion (OCL), a relatively weak and ineffective oxidizing agent. At pH 7-2 approximately 60 percent of dissolved chlorine exists as hypochlorous acid. As pH values increase, the amount of HOCL decreases and the amount of hypochlorite ion increases. At pH 8-5, the dissolved chlorine exists as 90 percent OCL and only 10 percent HOCL. Thus, it can be seen that the disinfection and oxidation properties of chlorinated water are six times greater at pH 7-2 than at 8-5. For this reason, a pH of 7-8 is generally the upper limit for swimming pool water containing chlorine residual in the range of 0-5 to 1-0 parts per million (p/m). If pH is allowed to exceed this limit, the chlorine dosage must be increased in order to provide an adequate supply of hypochlorous acid.

6-3. OTHER REASONS FOR pH CONTROL.

In addition to its serious effect upon disinfection and oxidation, pH fluctuation must be avoided for other reasons. At high pH dissolved minerals such as iron and calcium precipitate, adding turbidity and increasing soil removal demand upon the filter system. High pH in the presence of high total alkalinity contributes to scaling of filters, heaters, and piping. As pH drops below 7-0 the condition of the water becomes progressively acidic, producing eye irritation, corrosion, and other undesirable effects. Below 6-5 water becomes corrosive and damaging to metals in the recirculation system. pH ranges from 7-0 to 7-2 on the lower side and from 7-8 to 8-0 on the upper side are not objectionable, but they might well be thought of as safety zones to support the ideal range of 7-2 to 7-8.

6-4. FREE VS. COMBINED CHLORINE.

a. The potency of chlorine is affected by the ammonia content as well as the pH of the water. Ammonia is naturally present in virtually all surface waters and even more so in swimming pools since skin excretions and urinary discharges are ammonia sources. When dissolved chlorine exists predominantly as hypochlorous acid (HOCL) the residual is said to be "free available" chlorine . . . "free" to react with bacteria and other forms of soil. When chlorine reacts with ammonia the resulting compounds are called chloramines, and the chlorine becomes "combined" rather than "free" residual. Chloramines are undesirable because like hypochlorite ion (OCL), their oxidizing and germicidal power is greatly reduced.

b. The extent to which chlorine reactions produce chloramines rather than hypochlorous acid is governed largely by the amount of ammonia present. Chlorine prefers to chemically react with ammonia rather than with bacteria and soil. Thus, a large amount of ammonia in pool water causes the chlorine to exist largely as combined residual chloramine, greatly reducing the oxidation and disinfection activity.

6-5. SUPER CHLORINATION.

In the early history of swimming pool chlorination it was common practice to stabilize chlorine by adding ammonia to the water. The ammonia improved chlorine retention and prolonged the life of chlorine residual test readings, so it was reasoned that disinfection properties were enhanced by the method. Later studies, however, revealed the poor disinfection properties of chloramines. The practice has given way to a preference for burning out ammonia compounds through super chlorination (sometimes referred to as "breakpoint" chlorination).

6-6. BREAKPOINT CHLORINATION.

Breakpoint chlorination is accomplished by increasing chlorine dosage to a point at which all ammonia compounds in the water are completely oxidized and removed by chlorine reaction, after which point all dissolved chlorine exists as free available hypochlorous acid (HOCL) or hypochlorite ion (OCL). The amount of chlorine required to reach breakpoint depends upon the amount of ammonia present. Dosage instructions cannot therefore be expressed in pound or parts per million. An occasional super chlorination of 4 or 5 p/m in a typical pool will provide an acceptable means of assuring free residual chlorine.

6-7. INTENTIONAL CHLORINE STABILIZATION.

While the formation of chloramines in a swimming pool is considered objectionable, the stabilizing of chlorine with nitrogen compounds other than ammonia is considered desirable under some conditions. Such a practice may seem highly inconsistent with conclusions presented in the foregoing discussion, but the benefits to be derived become clear when the chemistry of chlorination is carefully studied.

6-8. STABILIZATION CHEMISTRY.

The hypochlorous acid molecule is highly desired for its oxidizing properties, but it is a highly unstable compound which rapidly dissipates in the presence of sunlight. This instability results in considerable chlorine waste, since free chlorine is rapidly destroyed even if it is not usefully consumed in reactions with bacteria and soil. Some degree of stabilization would therefore be desirable if such stabilization would slow the rate of chlorine dissipation without appreciably sacrificing oxidation and disinfection activity. Recently developed practices in swimming pool chlorination suggest that such stabilization can be accomplished satisfactorily with the use of cyanuric acid as the stabilizing agent. Chlorine reaction with cyanuric acid produces a relatively stable compound identified as chlorimide and, as in the case of chloramine formation, the dissolved chlorine exists predominately as combined residual. However, the chlorimide possesses significantly greater oxidation and disinfection properties than the chloramine group and is therefore an acceptable disinfection agent, whereas chloramine is not. Chlorimide reactions can also be produced with sulfamic acid and chlorinated chyantoins, but the use of these products is far less widespread than the chlorinated cyanurates.

6-9. STABILIZATION TECHNIQUE.

a. Laboratory and field studies of cyanuric chlorination technique suggest that, although the disinfection and oxidation properties of chlorimide are less than those of free hypochlorous acid, the loss can be at least partially offset by maintaining higher residuals of dissolved chlorine. It is generally believed that chlorine residuals in the presence of cyanuric acid should be maintained at 1-0 to 1-5 p/m, whereas 0-5 to 1-0 p/m is acceptable when free unstabilized chlorination technique is practiced.

b. The chlorinated cyanurates are used more commonly in private residential and small commercial pools at this writing. In larger swimming pools that are subject to heavy bathing loads, systems which provide free unstabilized chlorine residual are most frequently employed.

6-10. CONTROL OF pH AND CHLORINE RESIDUAL.

Oxidation and disinfection of swimming pool water can be accomplished only when adequate chlorine residual and proper pH values are maintained. The pool operator must therefore understand what factors cause pH fluctuation and chlorine dissipation and how to control those factors through proper chemical feeding practices.

6-11. CHLORINATION CONTROL.

a. Chlorine consumption and feed rates are easier to understand than pH control. As discussed previously, chlorine reacts with and destroys virtually all organic and inorganic compounds in pool water. In the process, the chlorine itself is destroyed and must be replaced. Therefore, the rate of feed is dependent upon the quantity of soil present in the water which, in turn, is largely dependent upon the bathing loads, bather preparation, weather, etc. It must also be remembered that free available chlorine dissipates even if it is not consumed by soil, so some chlorine feed is necessary even during periods when the pool is not in use.

b. Generally, knowledgeable technicians and public health personnel believe that free chlorine residual of not less than 0-5 p/m should be maintained at all times in the swimming pool. The better and safer practice is to feed at rates calculated to provide 1 p/m residual, with occasional super chlorination of 2 to 5 p/m, depending upon ammonia content and chlorine demand of the water.

6-12. CHLORINE TEST PROCEDURE (DPD METHOD).

The presence of chlorine is tested by use of a colorimetric test using N, N-diethyl-p-phenylenediamine (DPD) as a reagent chemical. The chlorine test procedure (DPD Method) is outlined in appendix C, Measurement of Residual Chlorine (DPD Method). The test is usually made periodically with the operator adjusting the chemical feed rates to compensate for the rise or fall of the residual. The experienced operator learns to sense

chlorine demand by observing bather loads, weather conditions, temperature, sunlight, and other influences. The periodic tests then are more often a confirmation of proper feed rates than a signal that rates need to be changed.

6-13. pH CONTROL.

a. The control of pH can be considerably more complicated than control of chlorine concentration. The chemistry of the pH factor itself is considerably more subtle than chlorine hydrolysis, and the factors which cause pH fluctuation are usually quite confusing to the nonchemist. However, the methods of control can be made reasonably clear. pH control begins with determining the pH of the water supply used initially to fill the pool and thereafter to make up water loss. Using the colorimetric test with phenol red reagent, the pH of the raw water is ascertained and then adjusted, if necessary, to the range of 7-2 to 7-8. Subsequent pH fluctuation is caused largely by the type of chlorine source used for oxidation and disinfection. Gas (elemental) chlorine, the most commonly used chlorine source in large swimming pools, decreases pH while the commonly used calcium hypochlorite and sodium hypochlorite sources tend to increase pH. Thus, if gas chlorination is practiced a substance must be fed concurrently to counteract the pH lowering effect of the gas chlorine. Soda ash, fed pound for pound with chlorine feed, is normally used for this purpose.

b. To counteract the pH elevating effects of sodium hypochlorite and calcium hypochlorite an acid counteractant must be used. Normally, pH control during hypochlorination is accomplished by feeding muriatic acid or solutions of sodium bisulphate.

c. The effect of chlorinated cyanurates upon pH has often been found to be very slight compared with gas chlorine and hypochlorites. Consequently, the pH is normally adjusted by occasional manual dosage of the counteractant rather than by feeding concurrently with the chlorine source.

6-14. pH EFFECT.

A number of other environmental conditions can affect the pH of swimming pool water; however, their enumeration would probably misplace the emphasis upon chlorination as the principal factor. For the most part, it is enough to say that when pH strays from the ideal zone of 7-2 to 7-8, regardless of cause, it should be promptly corrected. The operator must understand, however, that there are conditions under which the pH response to adjustment may be erratic and unpredictable. For example, a high pH of 9-0 might be adjusted to 7-8 by adding muriatic acid, only to ascend again to 9-0 within a few hours. Or, adding a small amount of corrective acid or alkali might produce a major response, sending the pH radically to an extreme high or low reading. Such reactions are attributable to the "total alkalinity" of the pool water and may indicate the need for corrections other than the addition of acid or soda ash. It is becoming common practice to equip swimming pools with testing equipment to measure both total alkalinity and pH, thus enabling the operator to make the necessary adjustments.

6-15. TOTAL ALKALINITY CONTROL.

a. Total alkalinity might be said to be a measure of the extent to which water is buffered or made to respond to pH adjustment. Water containing very low total alkalinity will respond radically to the addition of acid or alkali for pH correction, while water containing very high total alkalinity might respond very little.

b. Generally, swimming pool water should contain a minimum of 80 p/m and a maximum of 200 p/m total alkalinity. If the test procedure indicates a need for correction, it can usually be made by treating the water once, or for a short period of time, after which pH control is routinely accomplished by the methods discussed above. Total alkalinity that is too low can usually be corrected by adding a sufficient quantity of calcium carbonate ($CaCO_3$) to bring the level to 80 p/m. The corrective measure for total alkalinity that is too high may be somewhat more complicated. Essentially, undesirably high total alkalinity is corrected by adding muriatic acid. However, a single dose of a sufficient quantity to reduce the pH to 7-5 might not hold the pH at this desired level. The reading may consequently rise again within a few hours. When such a condition prevails, the acid dose must be repeated until the pH stabilizes at a desired level and total alkalinity is reduced to less than 100 p/m.

CHAPTER 7

DISINFECTION AND OXIDATION PRODUCTS

7-1. GENERAL.

Historically, chlorine has been the primary disinfectant used in swimming pools, although bromine has also been widely used. Both chemicals are commonly referred to as halogens, a chemical term used to describe four related elements in the atomic table: chlorine, bromine, iodine, and fluorine. Although iodine has shown promise as a pool disinfectant and is currently the subject of considerable experimentation, its use has not become widespread enough to be included in this discussion. Algicides are used to assist the disinfection process and are therefore included. All pool chemicals must be handled and stored in accordance with the manufacturer's instructions. NOTE: Never mix chemicals together outside of the pool; rather use the pool as a buffer in the actual application.

7-2. CHLORINE PRODUCTS.

Chlorination, as the term implies, is the practice of introducing chlorine to pool water after it leaves the equipment either in its elemental form or as a chlorine-bearing compound. Regardless of the product used or the method of application, the goal is to achieve a chlorine residual possessing strong oxidizing and disinfecting properties. There are four chlorine sources that are commonly accepted as disinfection products.

7-3. ELEMENTAL CHLORINE.

a. Elemental chlorine is a greenish gas at room temperature. Packaged under pressure as a liquid in metal bottles, it is fed into the recirculation system by specially designed equipment. If the chlorine gas escapes from the container or feeder apparatus, it will aggressively attack virtually all surroundings, especially if water or moisture is present. It is also highly toxic to man. Because of the hazardous nature of chlorine gas, its proper handling must be thoroughly understood by those responsible for handling containers and operating feeding devices.

b. Normally, the cost of elemental chlorine is considerably less than the cost of commercial chlorine-bearing compounds. It is therefore the most commonly used chlorine sources in the large swimming pools where feed rates and consumption are high. The cost of the extra soda ash required for this type of chlorine must be taken in account in making any cost comparison.

7-4. CALCIUM HYPOCHLORITE.

a. Calcium hypochlorite is a relatively stable compound of chlorine and calcium, commercially packaged either as a coarse powder or in tablet form. It is a safer material than chlorine gas with respect to handling and feeding, but it may present serious problems if spilled or scattered in a moist or wet environment or if oxidizable material is introduced to the container. When applied to swimming pool water calcium hypochlorite reacts much the same as chlorine gas. It tends to release free chlorine from the stabilizing agent and the resulting hydrolysis produces varying chlorine reactions. Due to the relatively compact nature of the package material, calcium hypochlorite is a popular chlorine source in small-/medium-sized swimming pools. Although it is a more costly source than gaseous chlorine (in net yield), this disadvantage is somewhat offset by the relative ease and safety of handling, storage and feeding. The most commonly used calcium hypochlorites will yield 70 percent available chlorine by weight.

b. Calcium hypochlorite can be manually fed directly into the pool from hand-held containers to either facilitate super chlorination or as an alternate feed in the event of equipment failure. Normally, however, it is mixed with water in tanks or feed crocks and the clear liquid is fed to the recirculation system by mechanical feeders. Such feeders are adjustable to control rates of continuous or intermittent feed.

7-5. SODIUM HYPOCHLORITE.

a. Sodium hypochlorite is a liquid compound of chlorine, water and sodium which is usually packaged in carboys or drums. If properly stored, it will yield 10 percent to 15 percent net chlorine depending upon its method of manufacturer and the age of the material. Like calcium hypochlorite it is relatively safe and easy to handle and feed, but it is also a hazardous product to spill. Applied to pool water the hydrolysis reactions are essentially like those of other chlorine sources.

b. Because of the weight and bulk involved, sodium hypochlorite normally is used to chlorinate smaller pools ranging in size up to 75,000 gallons. For disinfection purposes its use with respect to pool size is limited.

c. Mechanical feeding is accomplished in the same manner and by the same type of equipment used to feed the mixture of calcium hypochlorite and water.

Sodium hypochlorite need not be premixed with water. It is a feedable liquid in its packaged form when the proper feeder is used.

7-6. LITHIUM HYPOCHLORITE.

Lithium hypochlorite is another of the dry chlorine compounds. It is a free-flowing granular sanitizer containing 35 percent available chlorine. The product is an inorganic material with the chlorine immediately available as in the other inorganic chlorine vehicles. It is completely soluble in pool water or may be made up in a solution and dispensed through a chlorinator. Stable under all normal storage conditions, it may be stored for extended periods without appreciable loss of available chlorine. It is an acceptable product for swimming pool sanitation and has all the attributes common to the other hypochlorites.

7-7. CHLORINATED CYANURATES.

a. Chlorinated cyanurate is a relatively new pool disinfection product and is not widely used in swimming pools.

b. Chlorinated cyanurate is available commercially in both white powder and tablet form. The most commonly marketed cyanurates contain from 60 percent to 85 percent available chlorine. The physical appearance, handling precautions, and techniques of feeding, etc., of this group of chlorine-bearing compounds are the same as calcium and sodium hypochlorite. The important product differences involve the chemistry of hydrolysis. The cyanurates provide chlorine residual which is relatively more stable and therefore longer lasting in pool water than that provided by elemental and hypochlorite forms. Although such stability reduces disinfection and oxidation properties, it may be desired for other reasons. Cyanurates are an advantage when chlorination is accomplished by intermittent hand feeding rather than by continuous mechanical application.

7-8. ELEMENTAL BROMINE.

a. Pure elemental bromine is a heavy, red liquid and, like chlorine, is an aggressive oxidizing agent. Bromine is a dangerous chemical in untrained hands. If spilled from its container, bromine will attack virtually all surroundings. Even the fumes from an uncapped container can injure people and damage surroundings. Any person exposed to bromine fumes should be checked by the base health department.

b. As a disinfection product, bromine has been demonstrated to be equal to chlorine in bactericidal efficiency, although the chemistry is somewhat different. The hydrolysis of bromine produces hypobromous acid which, like the hypochlorous acid product of chlorination, is the agent which destroys bacteria and oxidizes undesirable soil.

c. Commercially, elemental bromine is packaged in glass jugs specially crated to guard against shock damage and breakage in shipment and handling. The material is fed to the recirculation system through a brominator which dissolves the liquid bromine in a crock of water near the point of injection. Elemental bromine is more costly for equivalent disinfection values than gas chlorine, and normally more expensive than the hypochlorites and cyanurates.

7-9. ORGANIC BROMINE.

a. In recent years bromine has become available commercially for pool sanitation in bromine-coating organic compounds commonly referred to as hydantoin or "stock" bromine. In such forms bromine can be compared with hypochlorites and cyanurates except it is twice as heavy as chlorine but not as volatile in the pool atmosphere. Such products are more costly than elemental bromine and therefore less likely to be used in large swimming pools. They are far less hazardous to handle than elemental bromine, however, and therefore possess distinct advantages in dosing small- and medium-sized pools where cost is a lesser consideration.

b. Organic bromine is more costly than most of the disinfection products discussed here. It is a slowly dissolving solid which is normally fed to the recirculation system from a pressure vessel by the washing action of the recirculating stream of water. As a practical matter, the organic bromine compounds may be less adaptable to precisely controlled feed rates unless metered by positive displacement devices. The method has been systematically effective, however, in disinfection of private pools. Also, claims have been made that longer swimmer immersion can be effected, which is a factor for competitive and training pools.

7-10. ALGICIDES.

If the pool water takes on a greenish or mustard-colored cast or black or dark green spots appear on the surface finish, algae is probably present and an algicide should be used. An algicide is a chemical additive used to kill and prevent the growth of algae in swimming pool water. Algicides are formulated for their specific toxicity to algae as an aid to disinfection chemicals. Although algae growth can be inhibited by disinfection chemicals alone, there seems to be increasing acceptance and use of the algicides for reasons of economy because their use reduces chlorine demand. Since mercurials have been banned by The Environmental Protection Agency (EPA), phenol mercuric acetate cannot be used. Quaternary ammonium halides are not recommended as they may cause foaming, absorb on filter media, and increase chlorine demand. Copper compounds are ineffective against some algae. Copper sulfate can cause skin rash and turn hair green at high

concentrations as well as cause milky or inky precipitates in highly alkaline or sulphur-containing waters. Other copper salts can be considered safe to use if manufacturer's instructions are strictly followed.

7-11. PRODUCTS.

Unlike the relatively unstable hypochlorous acid product, algicides are highly stable and residuals can therefore be sustained by hand dosing once or twice per week. The most commonly used commercial algicides are compounds containing copper or quarternary ammonium chloride, or phenol mercuric acetate.

7-12. SILVER.

Silver has been used experimentally in the purification of water for many years but has never gained acceptance among public health authorities. There are many limitations which need not be discussed here. The primary shortcoming is the relatively prolonged "contact time" required for bacterial kill. It is also noted that silver has very limited oxidizing properties which, as discussed previously, are essential to overall treatment of pool water.

7-13. ULTRAVIOLET LIGHT.

Ultraviolet light has been discredited as a disinfection process for pool water. Although the ultraviolet light rays will destroy bacteria in a single exposure at a single location, there is no known way to disperse this germ-killing residual throughout the pool, bathers run the risk of infection. Ultraviolet light disinfection would require a continuously virtual floodlighting of the entire pool. Such a practice would involve risks greater than those of bacterial infection.

CHAPTER 8

GAS CHLORINATION

8-1. GENERAL.

Gas chlorination of swimming pools is accomplished by dissolving chlorine gas in a flowing stream of water and then injecting this stream into the recirculation system. The gas and water are mixed in a chlorinating device that is adjustable to control the feed rate, which is usually scaled in terms of pounds per 24 hours. Thus, a 50-pound chlorinator is capable of feeding 50 pounds of chlorine per day; a 100-pound chlorinator is capable of feeding 100 pounds per day, etc.

8-2. SIZING EQUIPMENT.

The size of a chlorinator needed for any given pool is determined by the size of the pool in total gallons or gallons per minute (gal/min) of the recirculation system. One common sizing formula accepted by most designers is to divide the gal/min of the system by eight with the quotient expressing the pounds per day needed. Thus, a pool that is recirculated at 800 gal/min requires a 100-pound chlorinator. This formula appears to size a machine at three to four times the average capacity needed daily; however, what appears to be oversizing is actually a safety precaution because of the hazards involved in high volume chlorine feeding from a single tank through a single chlorinating device.

8-3. FEED RATE.

The actual feed rate for proper chlorination of a pool cannot be predicted by any standard formula. As noted in earlier discussions of the disinfection mechanism, the chlorine demand of the pool is determined by the quantity of bacteria and dirt, the size of the bathing load, the temperature, and many other factors. As these contaminating influences fluctuate, the rate of chlorination must be adjusted accordingly. The experienced pool operator soon learns "approximate settings" for proper chlorination under these varying conditions, based on trial-and-error adjustments determined by test kit readings of the pool water. Gas chlorination equipment operator training stresses safe handling of chlorine cylinders, connecting and disconnecting the chlorinators, and emergency procedures. (See figure 8.1.)

8-4. pH EFFECT.

The chlorine feed rate has a corresponding influence upon pH, so it is equally important for the operator to adjust the chemical feeding devices for pH control. Because gas chlorination lowers pH, the feeding of soda ash alkalizing agent must be increased when chlorine feed is increased and vice versa. Even so, the required feed rates are not precisely proportional; therefore, the alkaline feed rate must be determined by reading the pH of the water in the pool.

8-5. GAS CYLINDERS.

a. All containers used to transport liquified chlorine gas are Department of Transportation steel cylinders. Chlorine cylinders for pools are of seamless steel construction with an operating valve equipped with a safety device, a fusible metal plug. This plug is designed to melt at 158° F to permit escape of chlorine gas as an alternative to tank rupture. The fusible plug should not be tampered with under any circumstances.

b. The operating valve has a nonstandard pipe thread requiring a special wrench. The special wrench is intended to signal "danger" and to discourage the use of pliers, wrenches, or a hammer to force connections. The standard handling technique must be used.

8-6. CONNECTING CYLINDERS.

a. When connecting a cylinder to a chlorinator, special precautions should be taken to insure that the connections are secured before the operating valve is opened. After the valve has been opened, the connection should be tested for leaks that are too small to be detected by odor or by the sound of escaping gas. This is accomplished by holding an uncapped bottle of ammonia near all connections. Even the smallest leaks of chlorine gas will become immediately apparent as a chemical reaction between the chlorine and ammonia produces a white vapor cloud of ammonium chloride.

b. When a cylinder is empty the valve should be closed and tested for leaks, and the valve hood replaced. The empty tank should then be treated and handled as though full until it is removed from the premises.

8-7. CYLINDER LOCATION.

Chlorine cylinders and equipment should be located in fire-resistant, separate and enclosed indoor areas, accessible only to authorized persons. Such areas should be clean, well lighted, dry, and well ventilated, and should have at least two means of access and exit. One or more chlorine gas masks should always be on hand outside the storage room. Cylinders should be stored

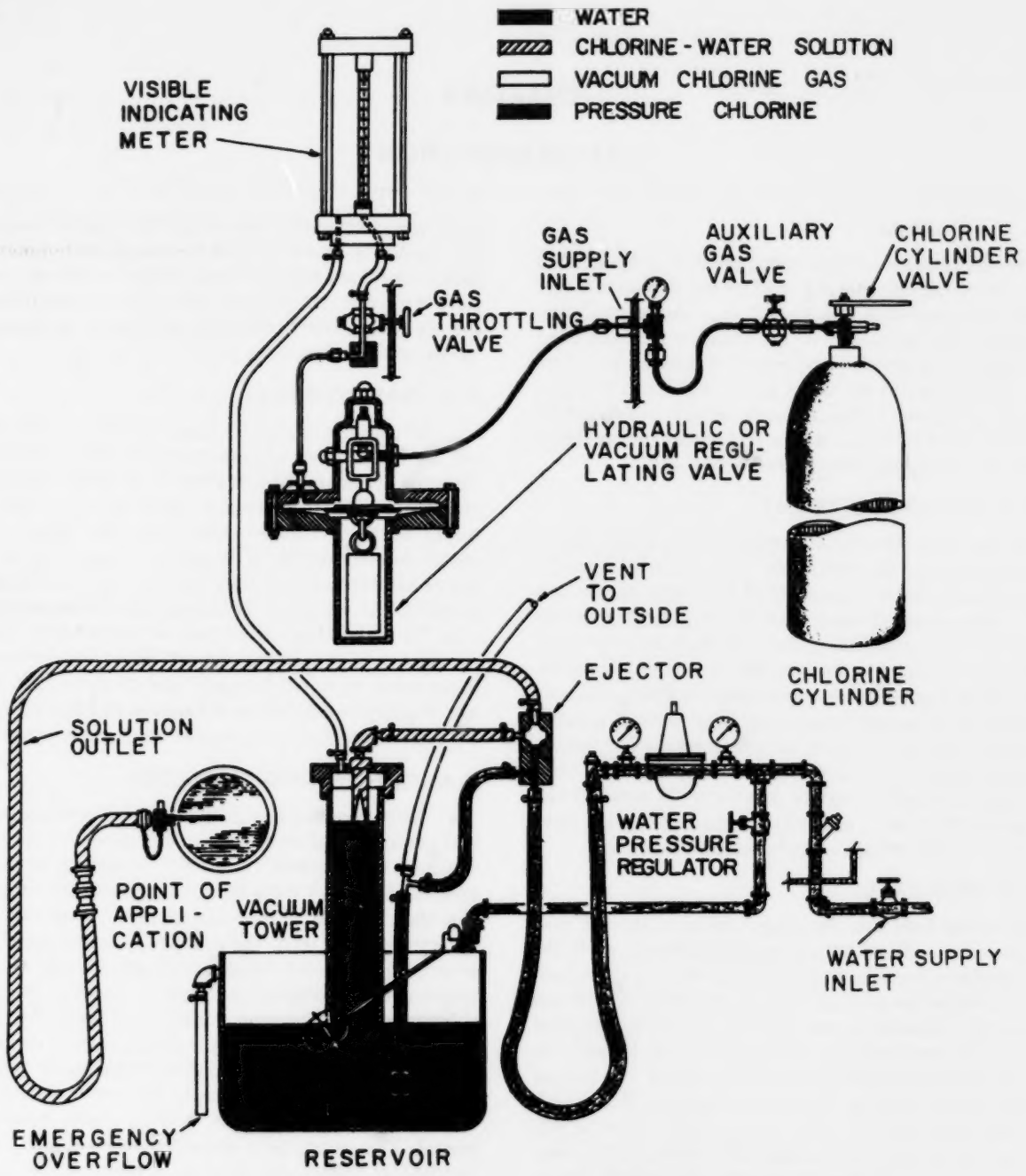


Figure 8-1. Flow diagram of manually controlled vacuum chlorinator

securely fastened in an upright position to prevent tipping or falling and in a location that avoids the possibility of being struck by heavy objects.

8-8. HANDLING AND STORING GAS CYLINDERS.

Cylinders should be moved on a properly balanced hand truck having a cradle or clamp support near the top of the tank. The cylinder should not be lifted or rolled by its protection hood. Chlorine gas cylinders should never be stored or handled near heat pipes or other external sources of heat. At room temperature a full chlorine cylinder contains approximately 90 percent liquid and 10 percent gas. As temperatures increase the resulting internal pressures increase the percentage of liquid and reduce the percentage of gas.

At approximately 154° F the container is completely filled with liquid. A further increase in temperature will cause the fusible plug to melt, permitting a rapid escape of the tank contents.

8-9. EMERGENCY PREPAREDNESS.

Safety in handling gas chlorine depends upon the effectiveness of employee training, proper safety instruction, intelligent supervision and the use of safe equipment. Employees should be thoroughly informed of the hazards of improper handling.

8-10. LEAK PROCEDURE.

Only authorized trained personnel, equipped with suitable gas mask, should investigate a chlorine leak. All other persons should be cleared from the area immediately and kept away until the leak is corrected. If the leak cannot be corrected promptly, the nearest office of any chlorine supplier or producer should be called immediately for assistance.

8-11. FIRST AID.

Any person overcome by or seriously exposed to chlorine should be moved at once to an uncontaminated area, and should be kept completely at rest and warm until medical assistance can be obtained. If breathing ceases, immediately apply artificial respiration or use approved inhalation equipment or oxygen.

CHAPTER 9

LIQUID CHEMICAL SOLUTIONS

9-1. GENERAL.

Liquid chemicals are used in swimming pools for three principal functions; disinfection, pH and alkalinity adjustment, and flocculation. Also, diatomaceous earth filter aid is fed as a liquid slurry, but it is not treated in this chapter. For disinfection, by far the most common chemicals are the chlorine sources. For pH and alkalinity control typical chemicals are soda ash, muriatic acid and sodium bisulphate. For flocculation, filter alum is common with soda ash added to provide sufficient alkalinity.

9-2. CHEMICALS.

a. For disinfection by chlorination, solutions of three primary compounds are used: calcium hypochlorite, chlorinated cyanurates, and sodium hypochlorite. The first two are normally dry powders, the third is a liquid. In practical swimming pool operation there are limitations on the strength of each chemical solution prepared.

b. The liquid sodium hypochlorite is typically furnished in concentrations of 15 percent or less. It may be fed diluted or full strength. Solutions of the dry cyanurates or calcium hypochlorite should be prepared according to manufacturers recommendations; suggested solution strengths are typically 2 percent to 5 percent.

9-3. STORAGE.

a. Solution preparation and storage is now simpler because of self-supporting polyethylene and fiberglass tanks. The heavy metal and ceramic tanks are less often used today. In general, it is desirable to use the largest solution reservoir, the weakest solution strength, and the highest chemical feeder output setting which is consistent with the space, personnel, and facilities available. The use of a relatively large solution reservoir permits the use of more dilute solutions which retain strength longer and permit operating the chemical feeder at a higher rate. A large reservoir also increases volumetric efficiency and accuracy, making possible better dispersal of the sanitizing agent in the water.

b. It is good practice to cover solution tanks not only to protect the solution but also to prevent the possible spread of vapors or fumes. Combination tank and feeder assemblies have a cover that serves as a support for the feeder. The feeder may also be located at the side or below the tank. Solution tanks must be properly maintained to assure accuracy and trouble-free operation of the chemical feed system.

9-4. SOLUTION PREPARATION.

The large solution reservoir makes possible the one-time preparation of a batch that will last a relatively long period. If calcium hypochlorite or other residue chlorines are used to prepare the solution, the two-tank system is recommended. That is, mix one tankful and allow the precipitate or insoluble material to settle before placing the intake of the chemical feeder in the tank. Then, while feed is being taken from the first tank, mix another supply in the second tank and allow to settle. Tanks are then alternated and the insoluble sludge which tends to settle out is cleaned from each tank prior to mixing a new batch. The use of corrosion-resistant plastic drain valves in plastic tanks makes this job easier.

9-5. LIQUID CHLORINE FEEDERS.

The chemical feed unit is composed of an assembly for handling the chemical solution and a mechanism for supplying the energy necessary to inject the chemical solution. The positive displacement type chemical feeder is the type most often used in public swimming pools although other types including drip feeders and venturi or differential pressure feeders are used. Chlorination should occur after the water has left the equipment.

9-6. POSITIVE DISPLACEMENT TYPE FEEDERS.

Most positive displacement type feeders have at least two check valves and a piston or diaphragm which transmits the energy of the drive mechanism to the pumped solution. The check valves must operate properly in order to assure performance of the pump. Although chemical feeder manufacturers have gone to considerable length to design valve systems that will handle comparatively large amounts of dirt and particles, solutions must be kept clean.

9-7. FEEDER FOULING.

A pool operator should expect to see scale developing in a chemical feed system. The rate of development is affected by type of source, solution temperature, feed velocity, and the hardness of the solution makeup

water. The scale can be dissolved by periodically feeding a dilute acid through the entire solution handling assembly of the chemical feed. This is done by placing the solution intake point or foot valve in a small reservoir of dilute muriatic acid or vinegar and operating the pump until the scale is dissolved.

9-8. SETTING FEED RATES.

a. Some chemical feed systems have timers or interrupter mechanisms to control their feed. The pump is operated for a portion of the total filter cycle rather than continuously. This permits the chemical feed system to operate at a higher volume per unit time and thus assure greater volumetric efficiency. That is, greater accuracy is achieved in feeding at a rate of ten gallons per day than feeding at a rate such as 1 quart per day. The technique of interrupted feed, in fact, makes it possible to feed hypochlorites at a maximum possible concentration and reduce the frequency with which the solution reservoir must be refilled. For a 30,000-gallon pool, for instance, it is possible that one filling of a 50-gallon reservoir of sodium hypochlorite will last 2 weeks or more. During this time chlorine would be fed regularly without further attention.

b. All swimming pool chemical feed equipment should incorporate a method for varying the output of the system. Residual tests will indicate if a change in the output of the system is necessary to maintain the residual. After some experience, the skilled operator anticipates the need for change according to sun conditions, bather load, wind conditions, and other factors requiring either more or less chlorine feed.

9-9. EQUIPMENT SERVICE.

An important, but frequently neglected, consideration is equipment service. Most manufacturers of swimming pool chemical feed equipment service their equipment through local offices, distributors, or service companies.

9-10. SERVICE SCHEDULE.

Most swimming pools have at least a brief shutdown period during the year. Because of the nature of the chemical feed system and its exposure to solutions which are corrosive, may be highly acid or caustic, and may tend to form scale rapidly, it is important that the system receive at least an annual check as part of the pool maintenance routine. This annual check, some modest care in maintaining clean solutions, periodic acid cleanouts to remove scale, and conscientious output adjustments in response to residual tests will make it possible for an operator to have a safe and clean pool at all times.

CHAPTER 10

THE RECIRCULATION SYSTEM

10-1. GENERAL.

The recirculation system is best described as a type of transportation system which keeps the water constantly in motion. A recirculation pump delivers water from the pool to an equipment station where it is filtered, chemically treated, and then returned to the pool. A strong chlorine residual for disinfection and oxidation purposes is carried with the water as it reenters the pool. Each of the devices and components encountered by the pool water as it recirculates is discussed. Chlorine and pH feed may be provided after the water is filtered. This is especially applicable in cases where sand filters are used.

10-2. PIPING.

Though copper pipe is acceptable, most pools use one of several types of plastic for piping and fittings. Low cost, complete resistance to corrosion, good flow characteristics, flexibility, and ease of installation make plastic practical for all pool piping. Some local building codes have not yet accepted plastic pipe, but those local codes that do allow plastic pipe usually specify the allowable plastic types and wall thicknesses. Steel piping should not be used in swimming pool recirculation systems.

10-3. DRAINS, OVERFLOW GUTTERS AND SURFACE SKIMMERS.

Water for recirculation is removed from the pool through two main drainage systems.

a. Some water is removed through the main drain at the deepest point of the pool. This enhances the removal of heavier-than-water particles such as sand, silt, etc. Main drain removal also contributes to mix-and-flow characteristics of the main pool water and the constantly returning water that is introduced at multiple inlets at the periphery.

b. Some water is taken from the surface of the pool and is removed through the overflow system consisting of overflow rims or skimmers or combinations thereof. Surface water removal is important since the top few inches usually contain the highest degree of contamination due to oral and nasal discharges, airborne pollution, insects, etc.

10-4. STRAINER.

a. After removal, the water flows through a piping system to an equipment area where all the water at a single point is strained through a sieve like device, a removable (for cleaning purposes) screen on basket, often referred to as the "hair and lint strainer" or "leaf trap." This device collects leaves, hair, lint, gravel, insects, and other relatively large particles which would clog the pump impeller or other parts in the system. The use of this device reduces filter loading and generally improves overall system performance.

b. The strainer must be checked often to prevent a progressive clogging condition. As the strainer becomes "plugged" with debris, the flow of water from the pool to the recirculating pump is impeded. Severe accumulations in the strainer prevent sufficient water from reaching the pump, causing a condition known as "cavitation" resulting in noise, vibration and erratic performance in the pump. Prolonged cavitation will result in serious damage to the pump impeller, bearings, and seal.

10-5. FILTER PLANT.

Having been strained of debris, the water then flows to the filter plant for the removal of fine-particles such as dust, body oils, algae, slime, bacteria, coagulated material, etc. This filtration aids the chemical disinfection and oxidation processes which beneficially take place after the water is returned to the pool. The removal of undesirable materials is accomplished by several mechanical systems which are discussed in the remaining chapters. In the present state-of-the-art, pool filtration is achieved most commonly by particle entrapment in either (1) a bed of sand or (2) a thin cake of diatomaceous earth.

10-6. CHEMICAL FEEDERS.

As the pool water flows beyond the filters it is chemically treated. Chlorine disinfecting agent is added, pH adjustment chemicals are introduced, and the treated water is returned to the pool to destroy bacteria and oxidize other undesirable solids.

10-7. INLET DISTRIBUTION SYSTEM.

Reentry of pool water is governed by the location and sizing of inlets. When a swimming pool is in design stage great care is exercised to locate and size the inlets to obtain the best possible flow characteristics of the filtered and treated water. The inlet fittings are normally adjustable to control volume, velocity, and even direction in order to obtain overall system

balance. The object, of course, is to provide rapid and uniform dispersion of treated water.

10-8. SYSTEM OPERATION PARAMETERS.

The pool operator should, by reference to flow meters and manipulation of valves, maintain a constant flow rate of 85 gal/min plus or minus 10 percent. Such operation will provide a turnover rate consistent with good pool management practice. Refer to appendix D, Calculation of Turnover and appendix E, Pump Characteristics for further information. Because rate of flow is constantly affected by soil accumulation in strainers and filters, the operator must understand the function of these mechanical components in order to keep the overall recirculation system functioning efficiently.

CHAPTER 11

FILTRATION

11-1. GENERAL.

a. Filtration is the physical process of removing dirt particles and solids to prevent impeding the disinfection process. Filtration, capable of removing some bacteria, is *not* a disinfection process. Disinfection is the chemical process of killing disease-causing bacteria and other types of microorganisms by maintaining a uniformly dispersed residual of some chemical (usually chlorine) in pool waters.

b. The removal of bacteria by filtration is not considered particularly beneficial. The primary purpose of filtration is to remove all foreign particles which would otherwise increase the chlorine demand of the water, thus lowering chlorine residuals and weakening the killing power of the chemicals that have been added to sterilize the water.

c. Many alternatives are open to designers and builders to accomplish particle removal through filtration. Of these, two primary filter types will be considered: sand (or permanent media) and diatomite. Both filter systems, if properly designed, are equally efficient and acceptable in delivering effluents of equal quality.

11-2. RECIRCULATION PUMP THEORY OF OPERATION.

The typical swimming pool recirculation pump is a centrifugal pump which imparts energy to the water by centrifugal force. Water is drawn into the eye of an impeller and then thrown from the outer perimeter of the whirling impeller into the volute or chamber enclosing the impeller. From the volute the water is forced into the piping system. If the water has been filtered prior to reaching the pump (at the suction side of the pump), it is discharged from the pump directly back to the pool. The filter system may be either a vacuum or gravity system. If the water has not been filtered, it is discharged from the pump to the filter station and then on to the pool. This system is described as a pressure system since the water is then normally delivered to the filters under pressure. Regardless of the system used, the hydraulic conditions encountered are much the same.

11-3. OPERATING PARAMETERS.

a. As the soil removal process takes place in the filter medium, the dirt accumulation increases resistance to flow and eventually reduces the flow below the specified amount. At that point the filter must be cleaned. Conversely, when the filter is cleaned and returned to service, resistance to flow is at its minimum and flow is at its maximum. Thus, it can be seen that the swimming pool pump output varies constantly from beginning to end of the filter cycle. It is important to note that a large variation in the specified flow rate is undesirable. As filter clogging increases resistance, reduction of the filtration rate is obviously undesirable. At the other extreme, flow well above the designed filtration rate may shorten filter cycles.

b. As a practical matter the designer chooses the swimming pool pump by totaling all the resistances to flow which will be encountered in the circulation system and adding the resistance which will be encountered due to soil accumulation during the filter cycle. Using the sum of these resistances, the designer selects a pump which will deliver the desired flow against all the controllable conditions which are expected to be encountered in a properly operated system. The operator then becomes responsible for carrying out the intent of the designer. At the outset of the filter cycle the operator must adjust the flow control valve to protect the system against too high a flow. As the cycle progresses the operator must continue to adjust the control valve to keep the flow rate at its desired setting. When adjustments will not maintain adequate flow (due to dirt accumulation in the filter), the filter must be cleaned and restarted on a new cycle. All throttling of the recirculation pump should be done on the discharge side of the pump, never on the suction side.

11-4. FILTER TYPES.

The following five filter types are traditionally acceptable: (1) pressure sand, (2) pressure diatomaceous earth, (3) vacuum diatomaceous earth, (4) gravity sand, and (5) cartridge filters. The first three types are predominantly in use today.

11-5. CHARACTERISTICS.

From the viewpoint of soil removal efficiency, the three systems are considered relatively equal. However, each system possesses its own unique characteristics with respect to operating procedures and hydraulic response to dirt loading. For discussion, these filter types are divided into two general categories: (1) permanent media filters (predominantly sand, al-

though anthracite is sometimes used) in which the filter medium remains in the filter after the soil load is backwashed to a waste disposal area or sewer, and (2) disposable media filters (predominantly diatomaceous earth) in which the filtering medium and the accumulated soil are disposed of together. A new supply of the filter medium is deposited in the filter for each cycle. Volcanic ash and specially processed pumice are sometimes employed as filter aids in place of diatomaceous earth.

CHAPTER 12

SAND FILTRATION

12-1. GENERAL.

Of the two commonly used pool filter systems, the sand system is the easiest to understand. Soil is trapped in the filter bed by a combination of two processes: (1) gelatinous and mucouslike substances and oils tend to cling to the grains of filter sand, and (2) solid particles lodge in the extremely small spaces and voids between the sand particles. As these two dirt collecting mechanisms work together, the filter bed stores more and more dirt and becomes increasingly dense and resistant to flow. Ultimately, adequate flow can no longer be sustained and the filter must be cleaned by backwashing.

12-2. FLOCCULATION.

a. The accumulation of the gelatinous and mucouslike substances referred to above is often described as flocculation. A sand bed does not become an efficient filter until a sufficient accumulation of floc (fine soil) inhibits the passage of very small solids. As a result the sand filter has to operate 8 to 16 hours before attaining its desired efficiency.

b. The formation of floc (filter efficiency) can be accelerated by adding aluminum sulphate or potassium alum to the recirculation stream ahead of the filter at the outset of the cycle. This practice is not nearly as widespread as it once was, however, because flocculation materials are not effective except at high pH. Since a high swimming pool water pH is not desirable for disinfection and oxidation reasons, many operators reject the practice. Because the filter bed will floc itself in due time, an acceptable practice is to sacrifice the first few hours of efficiency in return for the longer filter cycles which are obtained by letting the floc develop from soil in the pool.

12-3. EFFECT OF CHEMICALS.

It is important to note that the dirt holding characteristics of a sand filter are also affected by the chemical treatment of the pool water. Good chlorination practice burns up many unwanted materials which would otherwise collect in the filter bed. Chlorination also breaks down soil barriers already accumulated in the filter medium, thus reopening clogged spaces and passages.

12-4. ANTHRACITE FILTRATION.

Finely crushed hard coal (anthracite) can be used as a filter medium in the same manner as sand is used. It functions in the same way but is backwashed at lower velocities to prevent washing the medium to wastewater during the cleaning cycle.

12-5. SAND FILTER TYPES.

Two types of pressure sand filters, rapid sand and high rate sand, are commonly used in swimming pools today; a third type, referred to as gravity sand, is used occasionally. Rapid sand is the traditional system developed many years ago; high rate sand is relatively recent technology.

12-6. RAPID SAND FILTER CONSTRUCTION.

a. The typical rapid sand filter is a round steel vessel approximately 5 feet in height loaded with a 24-inch-deep bed of sand supported on four layers of gravel graded to uniform size (see figure 12.1). The stratified gravel bed performs two functions in the sand filter:

(1) It serves as a barrier which prevents the sand from washing through the underdrain into the pool during the filter cycle.

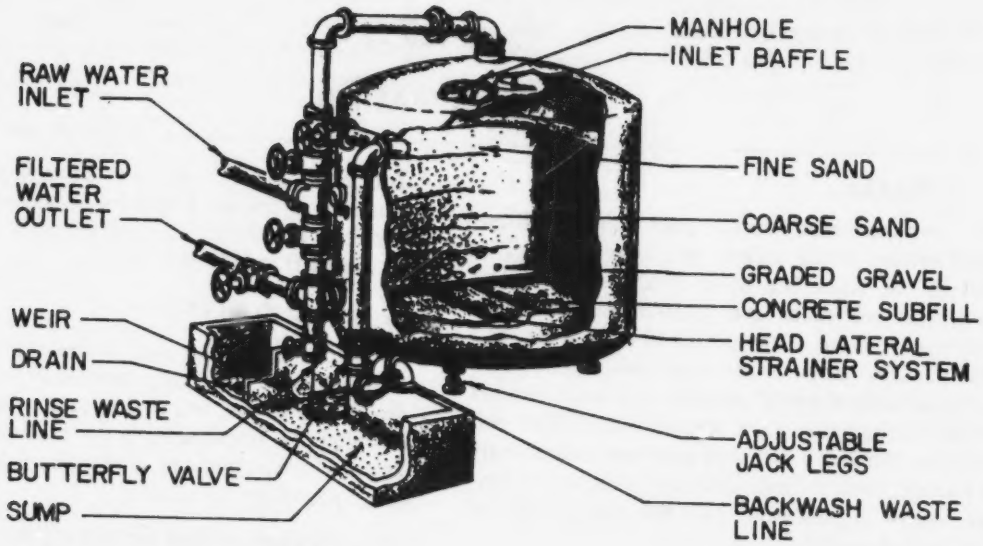
(2) It distributes the flow of water uniformly to the underside of the sand bed during the backwash cycle.

b. The size of sand particles in the filter bed is an important consideration. If the sand is too course, the voids between the particles are too large to trap fine solids. If the sand is too fine, the sand bed becomes too dense for dirt to accumulate between the sand grains. The ideal sand particle size for filtering has been established as 0.4 to 0.6 millimeters.

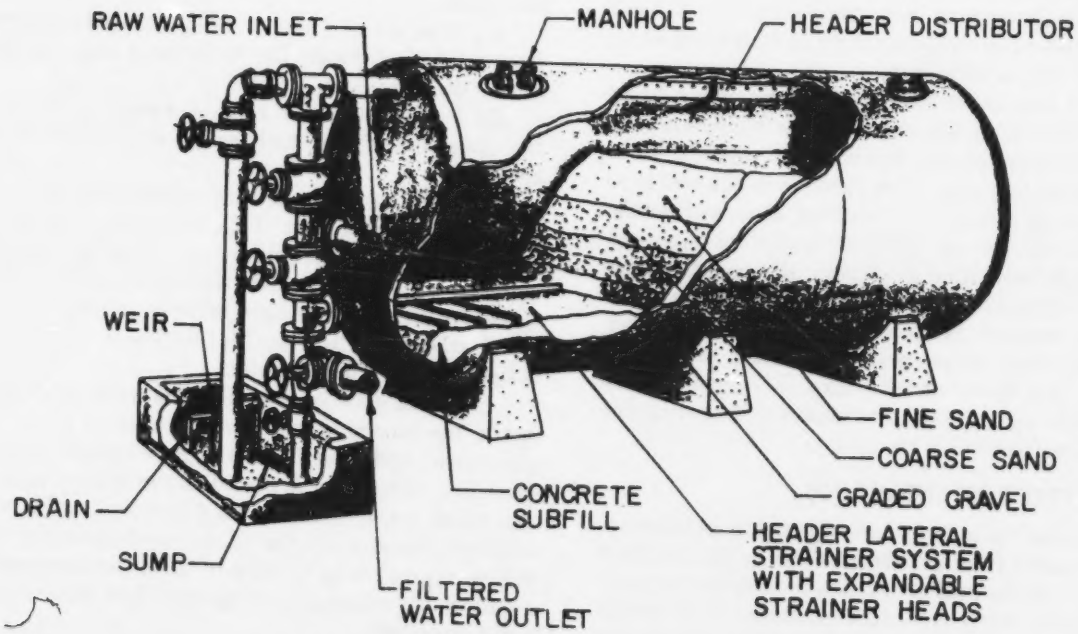
c. A splash plate is positioned above the sand bed to baffle the incoming water and prevent a direct impingement upon the filter bed. A perforated pipe or domelike underdrain is placed in the bottom layer of the coarse gravel to collect the filtered water for recirculation. The space in the filter vessel above the filter bed is referred to as "freeboard" area and is necessary to allow for expansion of the sand bed during backwash procedure.

12-7. RAPID SAND FILTER OPERATION.

a. Typically, the sand filter system on larger swimming pools is a battery of two, three, or four individual tanks manifolded together in order to receive relatively equal portions of the total flow during the filter



(1) VERTICAL PRESSURE FILTER



(2) HORIZONTAL PRESSURE FILTER

Figure 12.1. Manually operated pressure type rapid sand filters

cycle. This multiple cell arrangement provides an important accommodation to the backwash cycle. Since the sand filter must be backwashed at approximately four times the rate used during the filter cycle, the recirculation pump can provide the necessary backwash velocity only if the filter cells are backwashed one at a time. If the sand filter was a single vessel, a separate pump much larger than the one used for recirculation would be required for efficient backwash.

b. The diameter of the filter vessel is governed by the size of the pool and is specifically determined by the flow rate per square foot of surface area of the sand bed. The use of sand as a filter was introduced in the processing of public drinking water supplies, so the technology of sand filtration was quite naturally developed by public health agencies and the water works industry. During the development stage water was traditionally filtered at a rate of 3 gallons per minute per square foot (gal/min/ft^2) of sand bed surface area. Thus, if a given system requires a total flow of 600 gal/min, a filter system has to contain 200 square feet of sand surface area. Today it is still common practice to use 3 gal/min/ft^2 as a standard of design and operation of swimming pool sand filters.

12-8. HIGH RATE SAND FILTER CONSTRUCTION.

The typical high rate sand filter is a round pressure vessel with a special influent baffle in the top of the tank, a bed of filter sand, and a mechanical underdrain system to collect the filtered water for recirculation. The underdrain is often designed to serve as a barrier to the migration of the sand bed and as a backwash water distributor without the requirement of the stratified gravel bed which was traditionally used in the rapid sand systems.

12-9. HIGH RATE SAND FILTER OPERATION.

a. The total plant size and hydraulic characteristics of the high rate system differs substantially from the rapid sand filter. Instead of operating at the traditional flow rate of 3 gal/min/ft^2, it operates at flow rates of 15 to 25 gal/min/ft^2 of filter surface area. Because the total flow requirements of a given pool can be satisfied through a sand bed of considerably smaller surface area than in the case of rapid sand systems, the physical plant of the high rate filter is much smaller as well. It is therefore possible, for example, to adequately filter a 90,000-gallon pool through a single high rate filter tank 48-inches in diameter, whereas a rapid sand system for the same pool would require the use of a battery of three filter tanks, each 72 inches in diameter. Appendices F, Sizing a Rapid Sand Filter and G, Sizing a Diatomite Filter show the steps and assumptions for these calculations.

b. The high rate system provides an effluent of excellent quality, which appears largely due to its increased dirt holding capacity. The high flow rate drives the dirt load deeper into the filter bed, thus increasing the dirt-holding capacity of the medium. In the typical rapid sand system the primary soil load is confined to the top 2 to 4 inches of the sand bed, whereas the high rate filter collects soil through the entire depth of the sand bed.

c. The high rate filter system is normally backwashed at or near its filter flow rate of 15 to 25 gal/min/ft^2.

12-10. GRAVITY SAND FILTER.

The gravity sand system is an early swimming pool design that has been largely outdated by the pressure system which can be installed and operated in a much smaller area. Although the sand bed functions as a filter medium in the same manner in both systems, the gravity plant requires a much larger ground space than its equivalent pressure plant. Also, the backwashing procedure requires increases in both manual labor and water waste.

12-11. BACKWASH THEORY.

Backwashing cleans the filter by reversing the flow and causing the water to course upward through the bed. The backwash water action tends to slightly expand the bed, causing the sand particles to tremble and scrub against each other allowing the collected soil to break free and wash out of the filter vessel to a point of disposal. In rapid sand filter systems the backwash cycle is normally continued until the backwash effluent is observed to be free of soil, a period of about 8 to 10 minutes per cell. In high rate filters, backwash is accomplished in about 2 minutes because of the greater velocity of the backwash water.

12-12. BACKWASH OPERATION.

a. Backwashing the high rate filter is simple because there is generally only one tank in the system. However, the operator should understand the backwash function in the older rapid sand systems, based on several important observations.

b. The accumulation of foreign material in a swimming pool filter causes the soil to clump to some extent. Hair or lint often serves as a structure, and balls of organic material (mud balls) form and become imbedded in the top layer of sand. If backwash velocities are insufficient to wash the clumps to waste, they will work their way deeper into the filter bed creating channels which ultimately permit unfiltered water to take a path of least resistance through the medium.

c. Another undesirable result of insufficient backwash velocities is termed calcification. If the bed is not disturbed enough to expand slightly, it may eventually become encrusted with a cementlike mass and become

impervious to the flow of water. This phenomenon is particularly likely to occur if pH and total alkalinity of the pool water are permitted to become unreasonably high.

d. Both an inadequate backwash velocity and a backwash rate which substantially exceed 15 gal/min/ft^2 (25 gal/min/ft^2 for high rate sand filters) are undesirable. In some circumstances the full capacity of the recirculation pump will cause the sand and gravel bed to tumble and partially invert the sand layer and the layer of small gravel immediately beneath it. If this condition occurs, channeling can take place similar to that caused by the mud-balling described above. The condition can be corrected only by removing and reloading the first two strata of media.

e. As indicated in the above discussions, backwashing of the rapid sand filter system involves much more than a mere reversal of flow. The operator must establish the backwash flow rate with care to avoid the problems which result from either inadequate or excessive flow rates. In addition, the operator must comply with any discharge flow restrictions in the facility National Pollutant Discharge Elimination System (NPDES) permit. State and/or local authorities should be consulted for compliance advice.

12-13. EQUIPMENT INSPECTION.

Regardless of the protection methods used, the bed or the rapid sand filter should be periodically inspected. If signs of mud-balling or calcification are observed, the bed should be soaked with corrective chemicals such as acids and detergents.

CHAPTER 13

DIATOMACEOUS EARTH FILTRATION

13-1. GENERAL.

a. Diatomaceous earth filtration is commonly used for swimming pool water and makes use of a dirt-collecting medium which is discarded along with the dirt itself when the filter cycle is completed. Although three or four disposable media can be used in such systems, the one most commonly used is diatomaceous earth. It is therefore adopted as a term of reference to describe such filters throughout this chapter.

b. A cost comparison of different types of filters should be conducted before installing diatomaceous earth filters. These filters have a history of high maintenance and repair cost.

13-2. THE FILTER MEDIA.

a. To the naked eye, diatomaceous earth is a fine white powder, but under the microscope it is seen to possess certain unique properties which make it highly desirable as a filter medium. As an individual particle, it exists in many shapes, all of which resemble a petrified tumbleweed of near microscopic size. It resembles the tumbleweed because it is a lacy, weblike particle which is approximately 90 percent void and 10 percent solid fiber. It is petrified in a literal sense because it is the rigid, skeletonlike fossil of a very small form of plant life from prehistoric times.

b. The characteristics which make diatomite a filter medium can thus be seen when one imagines a cake or crust of small, rigid, porous particles piled one upon the other to form a fine screen, being placed in the path of a flowing stream of water (see figure 13.1). The openings in the screen are large enough to permit the flow of water, but small enough to obstruct the passage of virtually the smallest particle of foreign material. Even droplets of viscous oillike liquids will be caught in the screen. The diatomaceous earth filter cake is therefore a highly efficient filter medium, so efficient in fact, that it requires special care to keep it porous and functioning for extended periods of time.

13-3. THE FILTER SEPTUM.

All diatomaceous earth filters are equipped with septums (often referred to as the filter elements) or devices upon which the diatomaceous earth powder is collected in its cake form. The septum may be a cylindrical tube or a waferlike structure covered with a plastic or metal fabric of sufficiently fine weave to collect the filter cake. The septum is often a bundle of tubes, disks or wafers assembled to a pipe or pipe manifold which receives the filtered water and directs it through the recirculation system piping to the pool.

13-4. PRECOATING THE FILTER SEPTUM.

a. The act of depositing the filter cake upon the septum is called "precoating." It involves mixing a slurry of diatomaceous earth and water, and then introducing the mixture at a point in the recirculation system which will result in the slurry eventually being deposited upon the septum.

b. The precoat slurry formula provides for a precoat cake thickness of 1/16 of an inch minimum. This is accomplished by preparing a slurry which contains 1/10 pound of diatomite powder for each square foot of septum surface area to be coated. It is good practice to mix a slurry containing 1-1/2 pounds of diatomaceous earth powder for each 10 square feet of septum surface area because some of the slurry will pass through the septum and be deposited in the pool or delivered to waste during the initial precoating of the septum. A precoat thicker than 1/16 inch is not objectionable, but a precoat of inadequate thickness can be a serious operational error. An inadequate thickness will not only reduce filtration efficiency, but will also leave the septum fabric unprotected and exposed to direct soil accumulation. Septum fabric that becomes soiled with sticky organic material will not properly release its soiled filter cake during the cleaning (backwashing) cycle. As a result, the septum itself will become clogged with unreleased filter cake, reducing the available filter surface area and causing the filter to become short-cycled and inefficient.

13-5. CONTINUOUS BODY FEEDING THE FILTER.

a. An operator must understand the function of diatomaceous earth as a filter medium in order to understand why a single precoat of a filter septum will not keep a filter functioning for long. Because the soil is filtered out at the surface of the filter cake, the cake is soon slimed over and clogged with solids which inhibit flow. Such a condition produces very short filter cycles, making the diatomaceous earth system objectionable for this reason alone. It is possible to keep the filter cake porous and to increase its dirt-holding capacity by continuing to feed filter aid (diatomaceous earth) into the system through the process known as

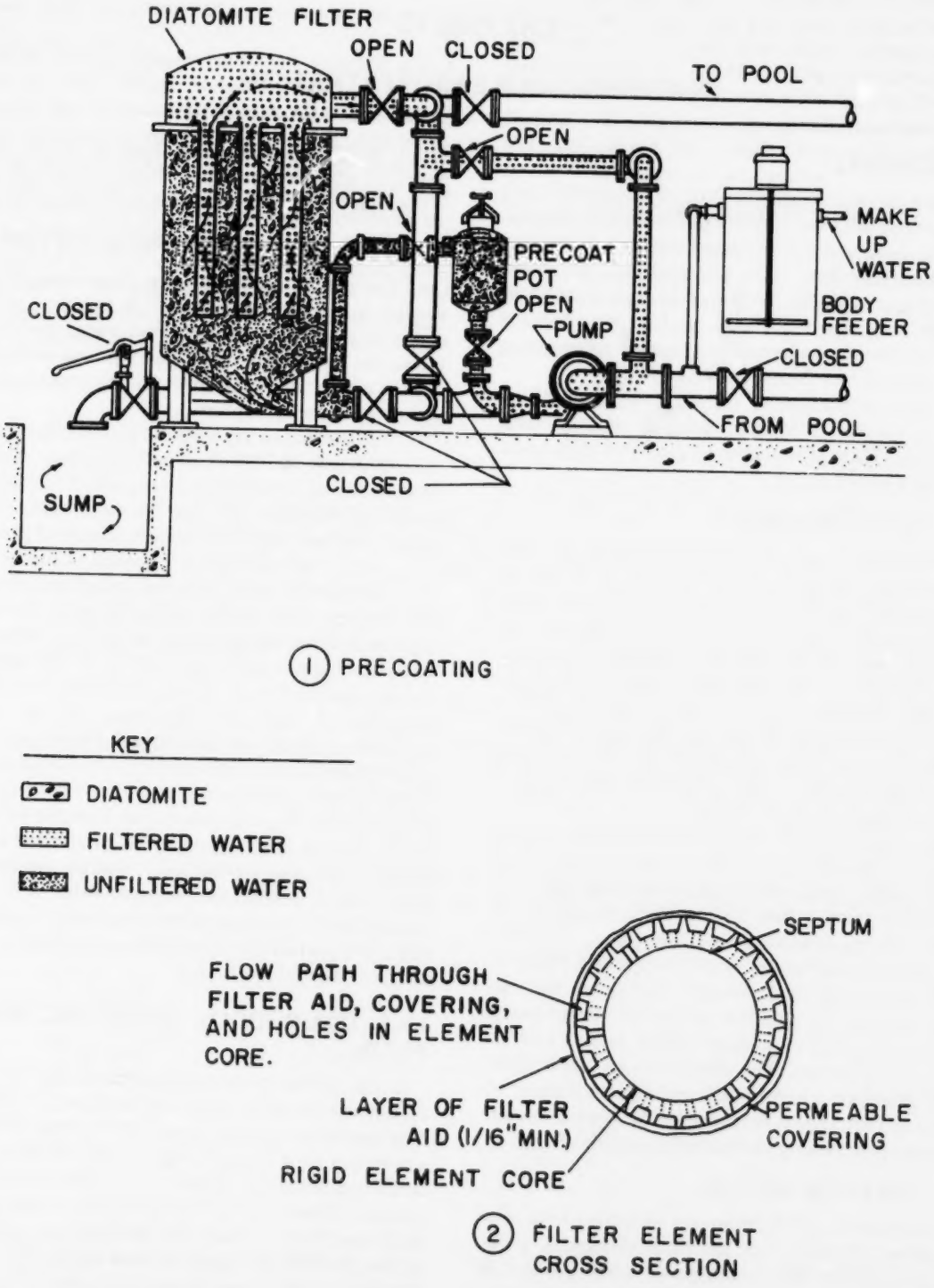


Figure 13.1. Typical diatomite filter

body feeding or slurry feeding. This involves introducing a continuous feed of diatomaceous earth filter powder into the unfiltered pool water as it approaches the filter system. By mixing the porous filter aid particles into the soiled water, the filter cake receives a mixture of particles, some of which are dirt solids, and some of which are porous diatomaceous earth particles which actually increases the dirt-collecting and dirt-holding capacity. Although body feeding causes the filter cake to swell and thicken, it increases its capacity to collect and store soil in the process, so the filter cycle is extended far beyond what would be provided if body feeding were not practiced. (See figures 13.2 and 13-3).

b. The slurry feeding technique is variable and controlled in a highly discretionary manner by the operator. If bathing loads are heavy, with resultant heavy dirt accumulation, the operator increases the rate of body feed. As bathing loads subside the experienced operator continues the heavy feed until the heavy soil accumulation has been largely picked up in the filter. The operator then reduces the rate of feed until the need for heavy feeding is again presented. Body feeding, like chlorine feeding, is measured against demand and the rates are adjusted accordingly.

13-6. THE PHYSICAL PLANT.

Understanding the functions of the filter medium and septum makes the diatomaceous earth filter plant rather easy to visualize. It may be either a closed tank which operates under pressure, or an open tank from which the water is drawn under vacuum to pump suction. In either case the system is comprised of a tank to receive unfiltered water, a septum to support the filter cake, and a pipe or manifold to collect filtered water from the septum and deliver it to the distribution system piping. In the case of the pressure type system, a crock or tank for precoating the filter is attached either to the filter itself or to the adjacent piping. Many shapes, sizes, and design configurations exist because there is a great deal of latitude with respect to septum design and collector piping arrangements. (See figure 13.4)

13-7. DRY FEEDER.

Two types of body feeding equipment are commonly used. The vacuum diatomaceous earth filter may be equipped with a "dry" feeder which consists of a hopper containing the diatomite charge positioned over the filter cell. A vibrator or other device may be used to deposit measured amounts of diatomaceous earth directly into the filter.

13-8. SLURRY FEEDER.

The more common system feeds the filter powder as a slurry. The slurry feeder consists of a tank containing a mixture of diatomite and water, a motor driven agitator or propeller to keep the diatomite in suspension, and a metering pump which draws the slurry from the tank and pumps it to the unfiltered water stream. A relatively dilute slurry is desirable because the diatomaceous earth particles tend to settle and pack or clog at points of low velocity in the pump, fittings, and solution tubing. A ratio of 1/2 pound of diatomite per gallon of water is probably ideal, but the ratio is not critical; much heavier slurries can be handled if the operator keeps the equipment functioning properly. Regardless of the ratio of diatomite to water, the slurry feed should be prepared daily, if possible, or at least every other day. The diatomaceous earth particle is very brittle and prolonged agitation in the slurry tank will tend to fracture the particles and greatly reduce their efficiency as a filter medium. (See figure 13.5)

13-9. FLOW RATES AND FILTER SIZING.

a. As in the case of the sand filter, the size of the diatomaceous earth filter is governed by the size of the pool. However, because diatomaceous earth filtration is relatively new technology, an inherited flow rate is not available to serve as a guide in sizing the filter system. Instead, the optimum flow rates have been determined from experience in the laboratory and in the field.

b. Experience has shown that the filter flow rate is far more critical in the operation of the diatomaceous earth filter than in the operation of the sand system. It was noted that flow rates can be substantially increased in sand filtration without materially affecting cycles. The diatomite filter, however, gives markedly reduced filter runs as the flow rate is increased. Therefore, it has become common practice to use diatomaceous earth systems of sufficient size that they can be operated at filter flow rates of 1 to 2 gal/min/square foot of filter surface area.

13-10. GENERAL FILTER CLEANING.

The diatomaceous earth filter responds hydraulically to dirt loading in the same manner as the sand filter. As the medium clogs with soil its resistance to the flow of water increases, eventually requiring the medium to be cleaned and recharged with filter powder. The manner in which the filter is to be cleaned is largely predetermined by the manufacturer of the equipment, so there is little reason to discuss the various mechanical systems and procedures which are offered commercially. It is worthwhile, however, to examine the basic differences between the vacuum and pressure type systems.

13-11. VACUUM SYSTEM FILTER CLEANING.

The typical vacuum filter is an open tank. As the recir-

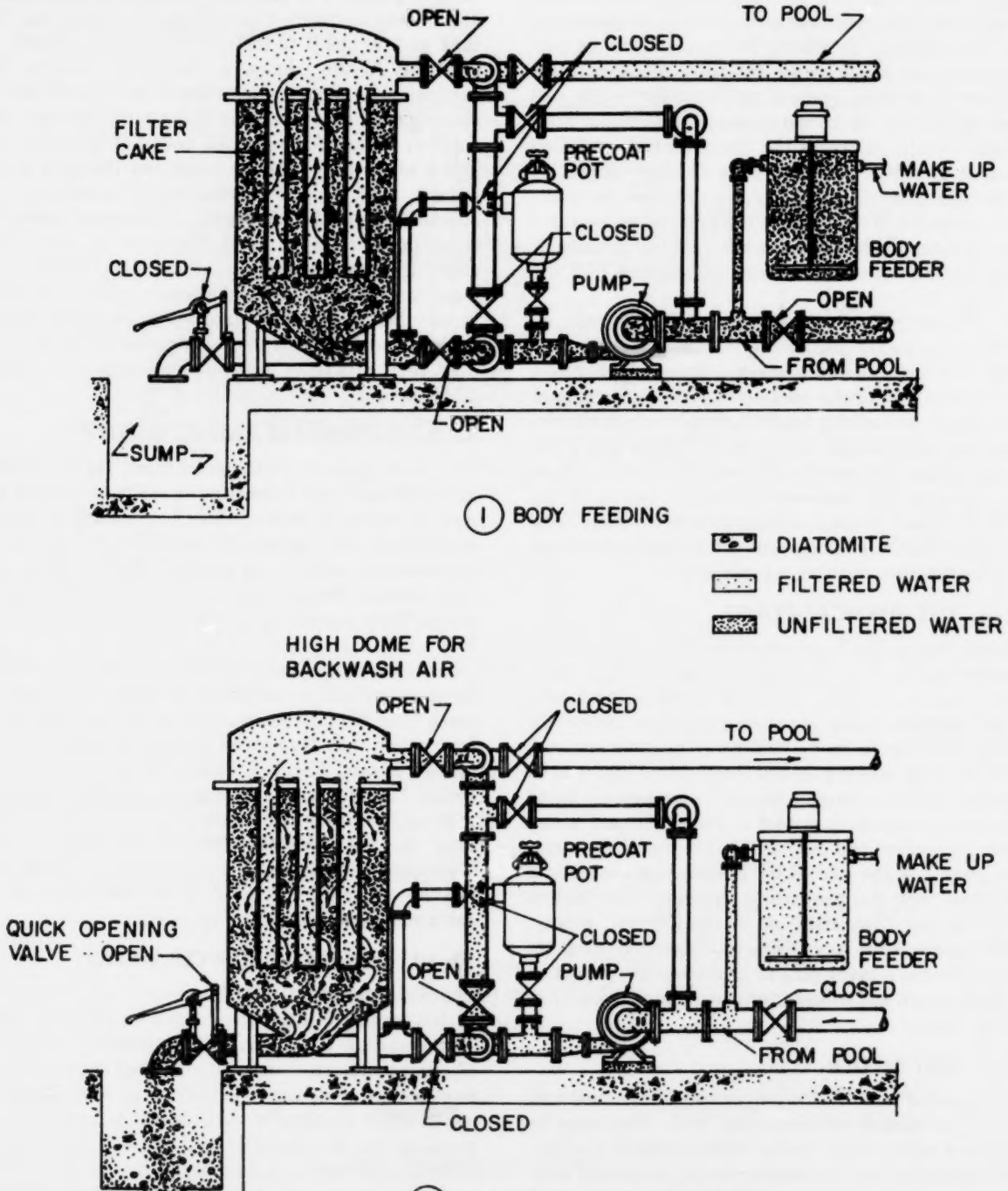


Figure 13.2. Body feeding and cleaning diatomite filters

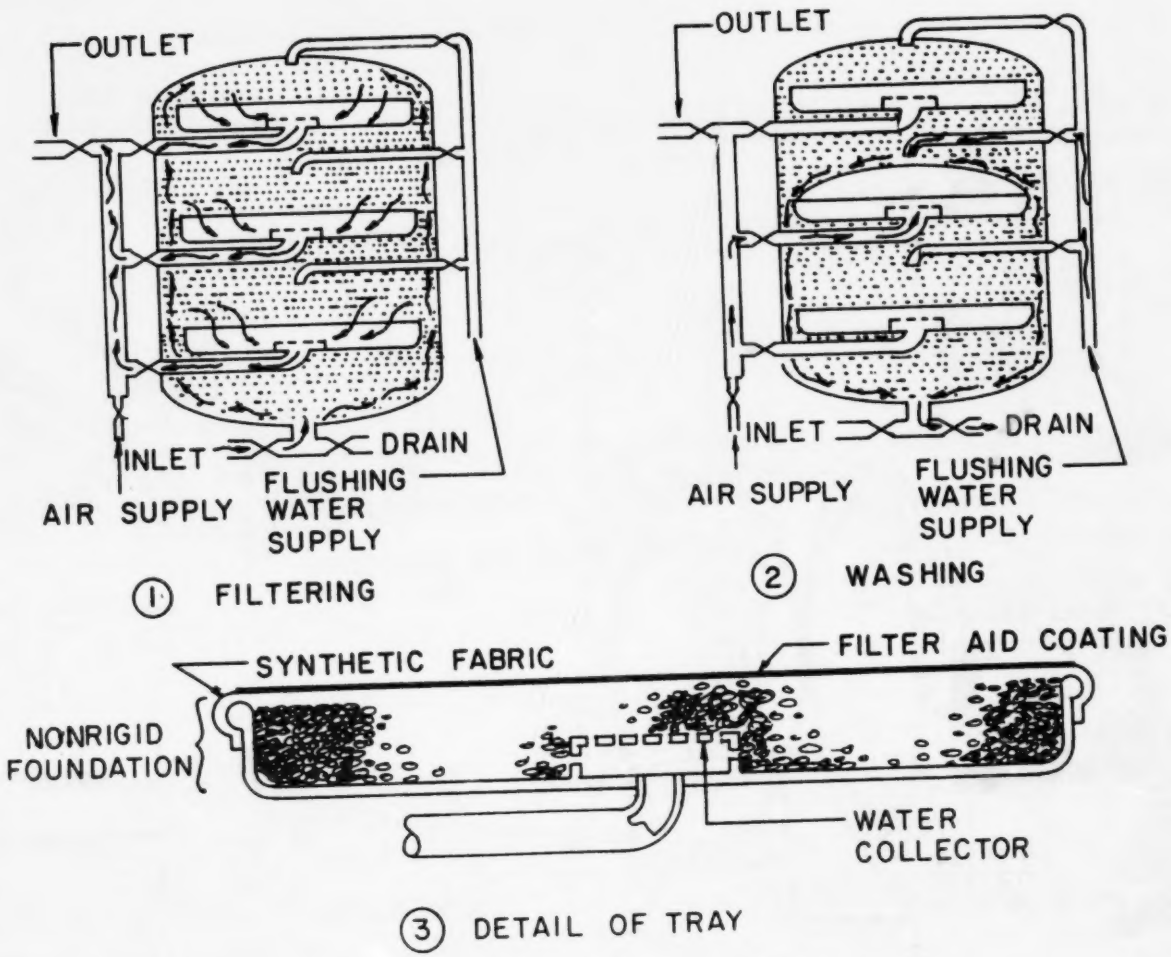


Figure 13.3. Tray type diatomaceous earth filters

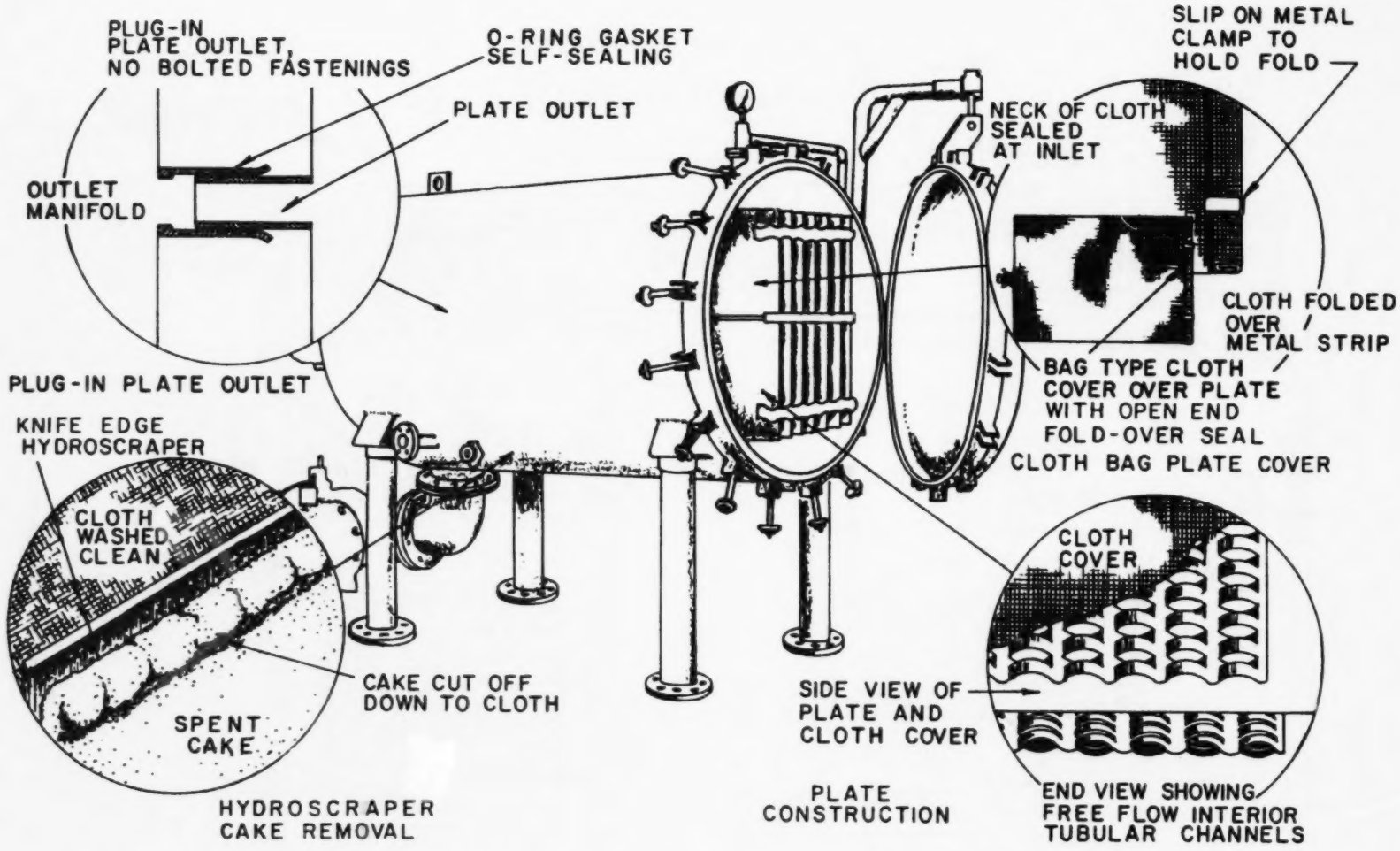


Figure 13.4. Typical heavy-duty diatomite swimming pool pressure filter with flat-type filter plates and cloth plate covers

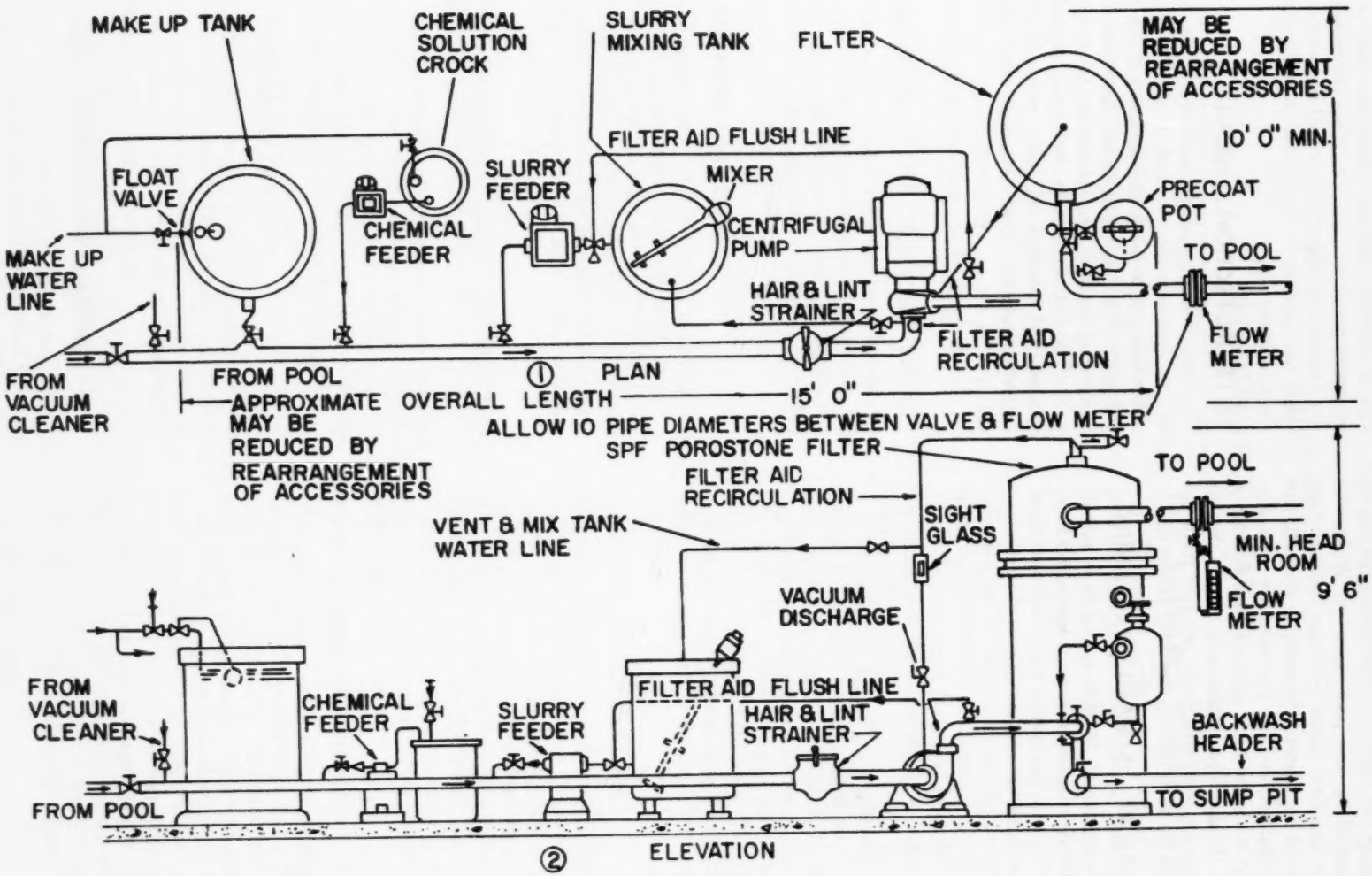


Figure 13.5. Typical filter room equipment

culation pump draws the water through the septum the dirt loading and buildup of the filter cake can be visually observed by the pool operator. When the vacuum gage and flow meter readings indicate that the filter should be cleaned, the pump is stopped, the filter cell is drained, and the elements are manually washed down with the high velocity stream from a garden hose. The operator should make certain that all the soiled cake has been effectively removed from the filter elements before returning the filter to service.

13-12. PRESSURE SYSTEM FILTER CLEANING.

The pressure diatomite filter is normally a tightly sealed vessel which cannot be readily opened for manual cleaning. Instead, the system has a combination of devices and procedures for reversing the flow of water through the septum, to jet spray the elements, or to flex or move the elements within the vessel to assist in releasing the soiled cake, etc. Also, the pressure filter is frequently equipped with visual inspection ports to assist the operator in appraising the efficiency of the cleaning operation.

13-13. INSPECTION SCHEDULE.

The best cleaning systems and techniques, however, will not prevent the eventual accumulation of some soil in the septum fabric and the loss of some filtration efficiency. For this reason it is good practice to periodically open the filter vessel and clean the septum manually. The filter elements and socks should be inspected and cleaned at least every other week. Diatomaceous earth filters should be rebuilt annually.

CHAPTER 14

SWIMMING POOL HEATING

14-1. GENERAL.

A swimming pool is a type of energy storage area with heat gains and heat losses occurring continuously. The amount of energy in the pool at any time is determined by the temperature of the pool. Heat gains from sunlight absorbed directly by the pool and from heaters either conventional, solar or both increase water temperature. Heat losses to the sky, to the surrounding air, and to the ground decrease pool temperature.

14-2. SOURCES OF HEAT GAIN AND LOSS.

Pool water becomes colder when energy is withdrawn through heat losses. Heat losses occur primarily at the surface of the water through evaporation, conduction and convection, and thermal radiation. Relatively little heat is lost to the ground.

14-3. EVAPORATIVE LOSSES.

These heat losses occur when the water at the surface of the pool is changed into vapor and carried away in the air. Besides decreasing the pool temperature, evaporation also results in significant loss of water and pool chemicals. Evaporation is increased by high windspeeds, high pool water temperature, high air temperature, and low relative humidity.

14-4. CONDUCTION AND CONVECTION LOSSES.

These losses are closely linked with evaporative losses and occur when heat from the pool surface is transferred to the cooler surrounding air. Conduction and convection losses increase with high windspeeds, low outside air temperatures, and high pool temperature.

14-5. THERMAL RADIATION.

Radiant heat losses occur when a warm pool radiates heat directly into the cooler sky, and account for about 30 percent of the heat lost from pools. These losses increase when the sky is clear, the relative humidity is low, and the pool temperature is high.

14-6. HEAT LOSSES TO THE GROUND.

The ground is a good insulator, so heat losses for an in ground pool comprise less than 10 percent of total lost energy. The typical above-ground pool with a vinyl liner and exposed sides has additional losses.

14-7. SWIMMING POOL HEAT GAINS.

a. Swimming pools are heated naturally through sunlight that is absorbed directly into the water and by the sides and bottom of the pool. Additional heat can be supplied by either solar, fossil fuel, or electric heaters.

b. The amount of sunlight absorbed by a pool is determined by the amount of sunlight reaching the pool surface multiplied by the fraction of light the pool actually absorbs. Such factors as location, time of year, and amount of shading control the amount of sunlight available to a pool.

c. The sunlight that is not absorbed by the water is reflected from the surface, sides, and bottom of the pool. Typically, about 10 percent of the sunlight reaching the pool is reflected rather than absorbed. Most of the reflection, however, occurs at the surface of the water—about 7 percent annually. The amount of sunlight reflected from the sides and bottom of the pool is small, because much of the light has been absorbed by the water.

14-8. POOL TEMPERATURE.

Medical authorities have determined that 78° F is the healthiest temperature for recreational swimming. Colder water results in a rapid loss of body heat, especially if swimming is prolonged. Excessive pool temperature, like excessive room temperature, is a wasteful practice. Additionally, an overheated pool causes chemicals used to purify the water to evaporate more rapidly at higher temperatures, resulting in progressively larger heat losses.

14-9. SWIMMING SEASON.

The use of most heated pools is seasonal, varying in length in the different climatic zones in the country. The National Swimming Pool Institute (NSPI) recommends that a pool operator determine the length of the season based on geographic location. In this regard the pool operator should be urged to do some planning. Some operators continue to heat their pools for weeks or months after regular usage has actually ceased. It is far better, and less expensive to turn off the heater at a predetermined date than to realize that the pool had not been used for a week or even longer.

14-10. HEATERS.

Swimming pool heaters can provide comfortable water

temperatures at night and during cloudy or cold weather. They can also provide auxiliary heat for pools using solar heaters and pool covers.

14-11. GAS AND OIL HEATERS.

After January 1, 1982, all new gas and oil heaters are to have a minimum 75 percent thermal efficiency compared with the previous 70 percent minimum thermal efficiency. If a heater must be replaced, the higher efficiency heater should be purchased.

14-12. ELECTRIC HEATERS.

a. Most electric pool heaters are found in areas where hydroelectric power is available; however, many are found in areas where gas was not available at the time of pool construction. In the past, cheap electric rates made them more attractive than oil- or propane-fired pool heaters.

b. Pools currently heated with electricity which is generated in substantial part by gas- or oil-fired steam-generating plants, should be under consideration for replacement with a gas- or oil-fired heater if either natural gas is available or a heating oil delivery system serves the installation. The replacement would probably be cost effective regardless of the operating condition of the electric pool heater.

14-13. ACTIVE SOLAR HEATING SYSTEMS.

a. Pool heating is the most practical, cost effective application of the sun's energy. Active solar systems can make a significant contribution to the heat required to maintain a pool at a comfortable swimming temperature. This contribution depends on the size of the collector area and its orientation toward the sun.

b. An active solar pool heating system can supply heat to pool water with only minimal use of conventional energy (that is, the energy needed to pump the water through the solar collector system). Active solar systems have been most successful as pool heating measures (approximately 93 percent of low temperature solar collector panels are used for pool heating).

c. The National Swimming Pool Institute recommends active solar systems for heating pools, where it is economical. Cost effectiveness depends upon the usage, the specific location, and many other factors. The cost of solar versus fossil or electric heating can only be compared by life cycle costing. The use of active solar panels to help heat pool water would be a commendable move in conserving non-renewable resources. Every site must be checked for adaptability for active solar. Pool solar systems usually require available panel space facing in a southwesterly (225°) direction of 75 percent to 80 percent of the pool surface area, and that space may not be shaded by tall trees or buildings. Local codes must also be checked. Reasonable planning and proper installation of solar systems nearly always results in approval.

d. An important consideration of the various economic criteria when adding a solar pool heating system is the justification of the relatively high, one-time investment in light of a payback analysis when compared to alternative methods of generating and conserving energy. With the continuing increases in fuel costs, this payback period will become more attractive.

e. It should be noted that a fossil fuel or electric heater may be required along with solar for a comfortable water temperature in a pool. For basic pool heating, the use of fossil fuels or electric heat is simply a backup to solar. However, this use allows quick heating of a swimming pool on days when the sunlight for the solar system is insufficient. (See figure 14-1.)

14-14. HEAT EXCHANGER.

When the proper chemical balance of pool water is not maintained the heat exchanger of the pool heater may become internally encrusted with scale, greatly reducing the efficiency of the heater. It is, therefore, a good conservation practice to have the heater serviced at least annually. This scaling can be minimized with the installation of a time delay timeclock (commonly known as a fireman's switch).

14-15. FUEL BURNERS.

Regular maintenance to prevent trash or leaves from blocking the burner draft ports will allow the heater to burn with the blue flame for which it was designed. Blocking the draft ports can lead to sooting and clogging of the burners, etc., and possible replacement of the burner or heater. Such blocking certainly causes the heater to burn more fuel than necessary.

14-16. WATER TEMPERATURE CONTROL.

The use of a thermostat on a pool heater is similar to the use of one for space heating and air-conditioning. Used correctly, the thermostat can save energy. Used improperly, it wastes energy.

14-17. THERMOSTAT SETTING.

a. A regularly used pool requires a thermostat setting at 70° to 80°. This setting should not be adjusted for personal preference.

b. There is less gas needed to reheat a pool for use over a weekend than is used by having the thermostat on all week to maintain a constant temperature, especially if a pool cover is not used to prevent heat loss. The amount of savings depends on the size of the pool, heater BTU rating (size), ambient temperature, humidity, wind, etc., and whether the pool is covered when not in use.

14-18. MANUAL CONTROL.

NSPI recommends that pool operators understand the

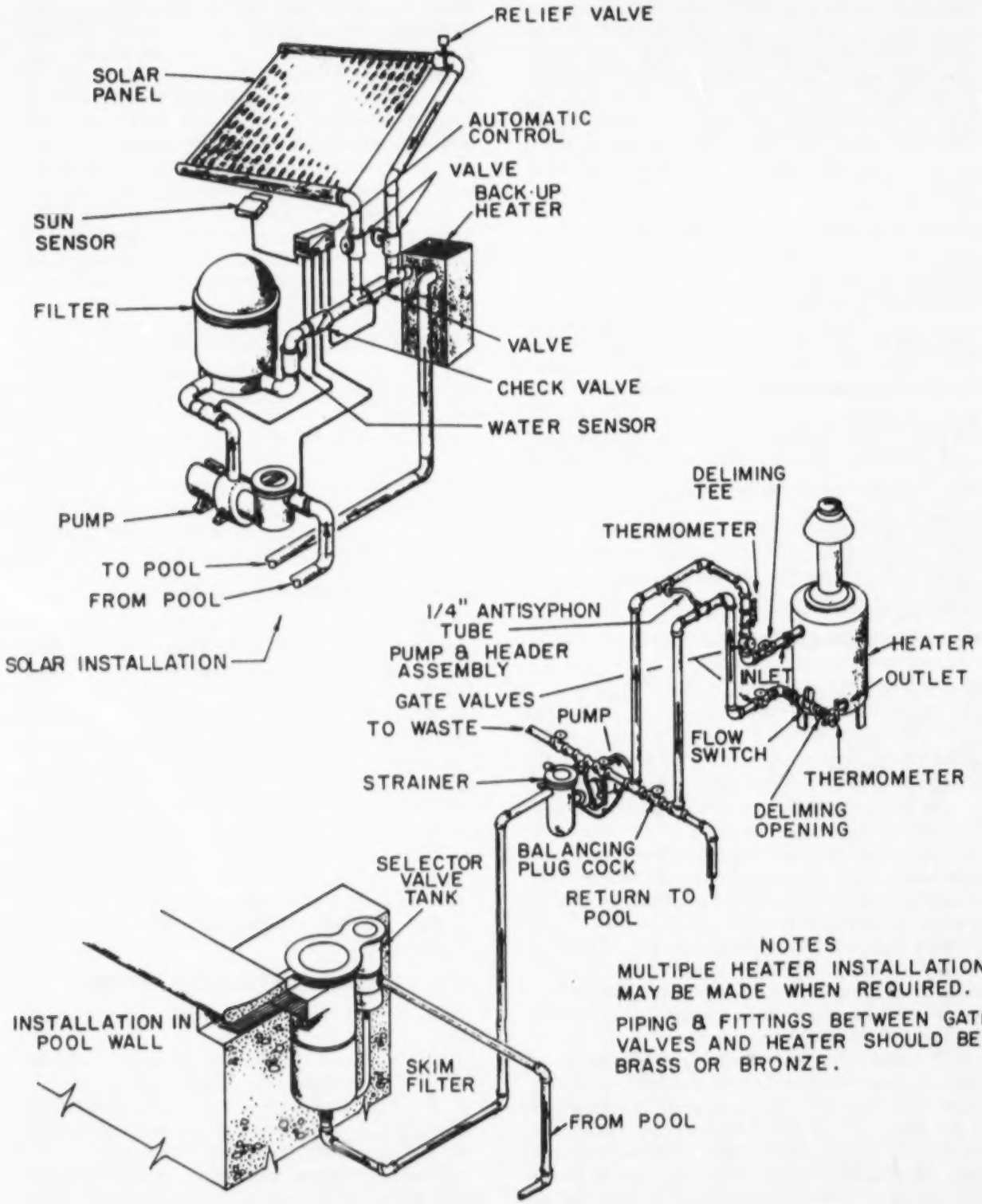


Figure 14.1. Typical swimming pool heater piping arrangement with skim type vacuum filter

use of a manual control system with the automatic thermostat on the pool heater. Pool heaters manufactured after January 1, 1981 are equipped with an on/off switch which overrides the thermostat and allows easy control for "occasional" heating. The on/off switch should allow the pool operators to turn the heater on or off without shutting off or relighting the pilot light, or adjusting the thermostat setting which can be permanently locked with a set-screw to avoid tampering.

14-19. ENERGY SAVINGS CONCEPTS.

Experience shows that energy is saved if a pool is equipped with a large, high-capacity heater to quickly bring a pool up to the desired temperature for an "occasion" and a small heater to make up the heat losses that occur during an extended heating period.

14-20. SWIMMING POOL COVERS.

Many technical papers have been written on the swimming pool as an efficient collector of available solar energy. These papers have illustrated that most of the heat lost from a swimming pool (more than 90 percent) is through the surface. The use of a pool cover prevents the waste of energy gains such as sunlight, solar collector systems, and fossil fuel or electric heaters. The swimming pool cover converts the swimming pool into a highly efficient energy storage system.

14-21. ENERGY SAVING POTENTIAL.

a. Proper use of a correctly sized and fitted pool cover can substantially reduce energy losses due to evaporation, radiation, and convection. Swimming pool water can suffer more evaporation loss than assessed through theoretical analysis. Consider the following: In summer months a swimming pool will lose an inch or more of water a week through evaporation. The heat of evaporation for water at 80° F is 1,047 Btu per pound. In a pool with a surface area of 600 square feet, 1 inch of evaporation would remove 3,121 pounds of water or nearly 3.3 million Btu's. This would cause a temperature drop of 10° F to 20° F in a 20,000-gallon pool. Evaporation is greatly affected by relative humidity and wind, which differ geographically in the United States. For example, evaporation loss is three times as great in Arizona (144 inches per year) as in Michigan (48 inches per year).

b. Thermal radiation or "black body radiation" is another major contributor to heat loss from swimming pools. Clear days and clear nights result in a major loss of radiation to the sky. In the more humid climates in the Eastern United States, much of the earth's black body radiation is absorbed by water vapor in clouds and reradiated to earth. Most studies indicate that an average of one-third of the energy from the sun is returned to space through radiation, particularly from surfaces that have emissivity near 1.00. The emissivity of water is 0.98. For that reason heat loss in a swimming pool can amount to as much as 100 Btu's per square foot per hour. This loss goes largely undetected because a body temperature of 98° F does not feel the radiation from a pool at 80° F. However, the radiated heat can be felt from a cement deck at 120° F or from asphalt or other black top surfaces.

c. By effectively limiting these heat losses from a heated swimming pool, the swimming pool cover can save 50 percent to 70 percent or even more, depending on the length of the season, of the energy used to keep the pool water at a comfortable 78° F. By far the most effective measure that a pool operator could take would be to use a pool cover.

14-22. TYPES OF POOL COVERS.

Although several types of pool covers are available, energy saving covers can be categorized into the following three types:

a. Translucent air cell
b. Insulating foam
c. Specialty

The effectiveness of each cover depends on its type and quality. There are distinct differences in their performance and energy saving capabilities.

14-23. BENEFITS OF POOL COVERS.

Quality energy saving covers should substantially reduce evaporative heat loss, water loss, and chemical consumption. Most covers will also help keep the pool clean by keeping dirt and debris out. Significant differences in these covers are based on the following three important performance characteristics:

a. Solar Transmission Value: Ability of a cover to allow natural energy from the sun to reach the pool water.

b. Insulation Value to Counter Night Heat Loss: Particularly losses from conduction and radiation.

c. Durability: Commonly measured by warranty life. Obviously, care must be exercised in the selection of a pool cover.

14-24. TRANSLUCENT AIR CELL COVER.

Characteristics of translucent air cell covers are as follows:

a. The pool cover transmits to the water at least 85 percent of the available solar energy striking it.

b. It is fabricated to prevent rainwater from collecting on the top of the cover and to prevent pool water from being exposed to the air and evaporation.

c. It is impervious to water vapor. (Should cover the entire surface of the pool in order to minimize water evaporation.)

d. It is constructed from translucent (may be tinted)

ultraviolet stabilized plastic of sufficient quality and thickness to remain serviceable in normal pool usage for several years.

e. It requires no tiedowns or weights to keep the cover in place during moderate wind velocities.

f. It will substantially reduce filter operation time.

g. It provides insulation for reducing nighttime radiation and conduction heat losses.

14-25. INSULATING FOAM COVER.

The most significant qualities of the insulating foam type pool coverings are:

a. Low solar transmission severely limits the amount of sunlight transmitted to the pool water.

b. It is constructed of an insulated and nonabsorbent buoyant foam layer and an upper reinforcing layer of tear-resistant material.

c. It is fabricated to prevent rainwater from collecting on the top of the cover and to prevent pool water from being exposed to the air and evaporation.

d. It is impervious to water vapor.

e. It is manufactured with sufficient ultraviolet stabilizers to provide a service life in normal pool usage of several years.

f. Material for both layers is generally polyethylene.

g. Cover should cover the entire surface of the water to insure maximum insulation and evaporation control.

h. Requires no tiedowns or weights to keep the cover in place during moderate wind velocities.

i. It will substantially reduce filter operation time.

j. It provides insulation for reducing nighttime radiation and conduction heat losses.

14-26. SPECIALTY COVERS.

a. Specialty covers fall into three broad categories:

(1) Safety covers

(2) Automatic pool covers

(3) Winter covers

b. Safety covers normally require some form of permanent installation to allow for rigid suspension over the entire pool surface and portions of the deck areas. This type of cover screens out leaves and debris. In addition, most safety covers minimize evaporation, thus reducing both water and chemical loss.

c. Automatic pool covers require permanent installation of "slide channels" under the coping or on the pool deck. This type of cover is motor-driven, making removal and replacement simple by merely "throwing a switch." This type of cover will reduce heat loss, keep dirt and leaves out of the pool, reduce chemical costs, and provide protection as do safety covers.

d. Both the safety type cover and the automatic type cover will retain pool heat and control water evaporation; however, both types have low solar transmission.

e. A winter cover is used to keep leaves and other debris out of the pool during the winter season.

14-27. HANDLING OF POOL COVERS.

The installation of translucent air cell covers and insulating foam covers requires only cutting and fitting to the pool shape. These covers should float on the water surface with as close a fit to the edge as possible. This avoids lifting by the wind. Specialty covers usually require professional installation. However, any operator can be taught to handle a cover alone. Some covers are fall folded; others have reel systems attached. If properly used, a cover will last several years. Most manufacturers warrant their products for several years, and useful life may exceed that by several more years with proper care, depending on geographical location and amount of ultraviolet light.

CHAPTER 15

MAINTENANCE

15-1. GENERAL.

Because pool equipment and its related piping and instrumentation vary from one pool facility to another, the operating, maintenance, and servicing, instructions provided in equipment manufacturer's literature will be used to augment the instructions provided herein. The different types of equipment and conditions under which they operate make proper lubrication extremely important. Improper lubrication (overlubrication as well as underlubrication) causes damage to wearing surfaces, increases maintenance costs, increases power consumption, and increases power outages. The use of cleaning solvents (types, hazards, and safe storage) in swimming pool water filtration plants, along with the use of mercury in manometers and other instrumentation is covered in the TM 5-660 series.

15-2. PREVENTIVE MAINTENANCE.

A preventive maintenance program, effectively implemented, will improve equipment operating performance and extend equipment life. In addition, preventive maintenance program records can be used as an inventory planning tool and as a manpower scheduling tool.

15-3. ESTABLISHING A PREVENTIVE MAINTENANCE PROGRAM.

Establishing a preventive maintenance program requires a record of past operating experience and the equipment manufacturer's recommendations in order to develop individual equipment maintenance and scheduling requirements. The actual process used to develop such a program is outlined in TM 5-652 (Steam/Hot Water Distribution Systems).

15-4. DAILY OPERATION PROCEDURE.

A swimming pool operating log, DA Form 3164-R must be maintained by pool operating personnel. All entries are to be made as soon as readings are taken. The accuracy of this form is important; do not enter readings as they should be, but as they are. DA Form 3164R will be reproduced locally on 11 inch by 8-1/2 inch paper. Copy for reproduction purposes is located at the back of the manual.

15-5. SEASONAL CARE.

Pools that are closed during winter should be inspected once a month during the off-season. Particular attention should be given to any moisture forming in the filter room or chemical storage area. If excess moisture is prevalent, diatomaceous earth filter elements should be removed and stored in a dry place to avoid corrosion. Chemicals stored during the off-season should be kept dry to prevent caking or corrosion. The off-season is considered a good time to paint interiors and to repair deck furniture, bathhouse facilities, and electrical fixtures and wiring.

15-6. POOL OPENING.

Before a pool is opened in the late spring or early summer, certain operation and maintenance routines must be followed. Several months prior to opening, a thorough inspection should be made of all equipment and supplies, including pool shell, deck area, pool inlets and outlets, control valves, drains, heaters, filters, pumps, chemical feed equipment, and electrical systems. Cracking or spalling concrete should be patched with special hydraulic cement or other approved compounds. If necessary, surfaces should be repainted using procedures recommended by the paint manufacturer. The amount and condition of filter media should be checked and replaced as necessary. Adequate chemical supplies should be ordered.

15-7. POOL STARTUP.

Pool startup includes the following procedures:

a. Chlorinator. The chlorinator should be checked in accordance with the manufacturer's recommendations. If chlorine bottles have been left connected since the last swimming season, they should be disconnected carefully by someone wearing an air pack or chlorine mask.

CAUTION

Where the chlorine bottles have been left connected to the chlorinator and the valve left on, a second person should be present (for safety) when the valve is closed. Valves often corrode under these circumstances and cannot be completely turned off. When this condition is found, the fitting should be cracked slightly and the presence of chlorine tested by holding an opened bottom of household ammonia close to the fittings; if chlorine is present a white cloud of ammonium chloride will be produced. If the valve cannot be com-

pletely closed, contact your supplier.

b. Soda Ash Feeder. This should be checked to see that it is working properly and that no dried soda ash is remaining inside.

c. Piping and Pumps. Check for proper pump operation and any deteriorated pipe. Where steel pipe has corroded, recommend replacement with PVC pipe.

d. Filters. Where diatomaceous earth filters are used the filter should be disassembled and its elements checked for leaks annually. If socks are used over the filter elements, they should be examined and replaced if holes or worn places are found. If the filter needs extensive repairs, it should be replaced with a high rate sand filter.

e. Sand Filters. Sand filters seldom need maintenance other than backwashing. Check to see that the pressure drop across the filter is not above the manufacturer's recommendation.

f. Paint. Where the walls of the pool require painting, use chlorinated rubber base paint. Do not use epoxy since it tends to chalk when exposed to sunlight (even under water) and tends to give the water a milky appearance.

g. Recirculating Lines. When recirculating lines have to be replaced use polyvinyl chloride (PVC) piping. It is not necessary to tear up the deck since the replacement pipe can be grouted into the right angle spaces between the pool sides and the bottom.

h. Chlorine and pH Test Kit. A copy of TB MED 575 dated Jun 82 should be obtained and used as a guide for swimming pool operations. A good chlorine/pH kit should be obtained and these parameters maintained in accordance with limits shown in Para 3-23d(2) of the TB MED. It is not necessary to obtain the LaMotte - Palin DPD Chlorine-pH test set described in appendix C of TB MED 575; it now costs $92.80. DBD Chlorine-pH test sets are available from other companies at lower cost. (Example: The DPD Chlorine-pH test set from the Hach Company costs $67.00).

i. Remove Floating Debris. Remove leaves and other floating debris from pool surfaces with a leaf skimmer.

j. Add water. If water is added to the makeup tank, the pump is started and the filters are placed in operation when the makeup tank is nearly filled. If water is added directly to the pool, allow the pool to fill approximately one-third full and then turn on the pump and filters. If the only return to the filters is from overflow of the pool, the pool must be filled and overflowed before water is available to the pump and filters, which should then be started. When sand and anthracite filters are first started, add floc and waste the filter effluent for a few minutes until effluent is clear.

k. Chemical Feed. Start chlorination as soon as filtration begins. Start pH control as soon as pH tests of the water indicate need. Take frequent pH and residual chlorine readings.

l. Reduce Water Supply. When the pool is filled, reduce the amount of makeup water from the water supply to the amount that will produce a constant overflow about 1/8 inch deep all around pool overflow troughs or deck level.

m. Final Check. When pool is ready for use, check turbidity, pH, temperature, alkalinity, and chlorine residual. Do not open pool until all readings are satisfactory.

15-8. POOL CLOSING.

The following procedures should be followed when closing outdoor pools at the end of the season.

a. Wash filters (backwash) several times thoroughly, perform any necessary filter cleaning with appropriate chemicals, and rinse with freshwater. Pump freshwater through all chemical feedlines and equipment. Carefully check operation of all equipment, including pump and motor.

b. Open main pool, filter, and other drains to dewater pool and equipment. Make sure there is a valve at the lowest point in piping system so that all water can be drained. Leave this valve and pool drain valves open to allow rain and snowmelt to runoff. In pools where it is necessary to maintain water to prevent the pool shell from cracking or floating out of the ground, close the main pool drains to maintain desired water level in pool. Drain the filters and all the piping system. Check the main drain valves to be sure there is no leakage.

c. Inspection. Make complete inspection of all equipment and supplies.

d. In order to prevent deterioration of equipment during storage, take the following steps:

(1) Open diatomaceous earth filters and check filter elements for cleanliness. If any dirt or grease remains on the elements, use a cleaner recommended by the filter manufacturer or higher technical authority. Handle elements carefully to prevent damage. After cleaning, reassemble and wash the filter several times.

(2) Drain all pipelines, pump cases, and the hair catcher. Clean the hair catcher buckets and store them in a dry place.

(3) Clean and recondition all check valves, sump pumps, sight glasses, gages, and meters.

(4) Thoroughly wash all pump bearings and pump motors with an approved solvent such as kerosene or other armed services approved solvents. Immediately fill bearings with an approved rust-preventive compound.

(5) Clean all oxidation from exposed copper surfaces on transfer switches, safety switches, pump starters, and other electrical equipment by burnishing the copper with a burnishing tool.

(6) In cold climates, remove and empty all traps in lavatories in the bathhouse.

(7) If the pool is to be left full of water, logs or other materials approved by higher technical authority should be floated to prevent ice damage. Material should be fastened to maintain spacing and prevent bunching. Plastic covers should be securely fastened to prevent algae growth and keep out debris.

(8) Remove ladders and clean them with a chrome cleaner or polish. Put one ladder back in place in the pool; store the remaining ladders in a safe place.

(9) Remove ladders and clean them with a chrome cleaner or polish. Put one ladder in place in the pool; store the remaining ladders in a safe place.

15-9. PREPARING UNPAINTED SURFACES FOR PAINTING.

Prior to painting, the unpainted concrete or tile surfaces must be cleaned of all dirt, oil, grease, or residual chemicals. Concrete surfaces may be cleaned with an 8:1 solution of muriatic acid (8 parts water to 1 part acid, by volume) and tile surfaces with 12:1 solution of muriatic acid (12 parts water to 1 part acid, by volume). The acid solutions should be applied with straw brooms, or plastic or fiber brushes. The acid solution should be left on the surfaces for 6 to 15 minutes before removal by flushing with clean water. All cleaned surfaces should be flushed with clean water under pressure at least four times in an 8 hour period. After the last flushing, random spot checks should be made with blue litmus paper to assure complete removal of the acid. The pH of the cleaned surface should be not less than 6.5. Surface cracks must be cleaned and filled with a suitable filler prior to painting.

15-10. SANDBLASTING.

Sandblasting should be utilized to remove grease, oil, and old paint. Iron or brass slag may be used as the sandblast media. Sandblasted areas must then be cleaned with acid (see paragraph 15.9) to etch the surfaces, and thereby improve the bond for new paint.

15-11. CLEANING STEEL SURFACES.

Exposed steel components of the swimming pool must be sandblasted and wiped clean of dirt and dust before painting.

15-12. PAINTING CONCRETE SURFACES.

After the pool surfaces have been throughly cleaned, patched, and dried (allowing at least 16 hours drying time), paint the surfaces with material conforming to Federal Specification TT-P-95, Paint, Rubber-Base (for swimming pools). The first coat will be thinned, using 1 gallon of paint to 1 quart of xylol, and used as a primer sealer coat. After drying for 16 hours, brush on one or two coats of the paint. Thinning is permissible for spray application. A drying time of 16 hours is required between coats, and at least 5 days after the final coat before filling the pool with water. For further information, reference Army TM-5-618, Paints and Protective Coatings.

15-13. PAINTING STEEL SURFACES.

Exposed steel surfaces will be prime coated immediately after cleaning to prevent rusting. The primer used will conform to Military Specification MIL-P-12472, Primer coating, Phenolic, Water Immersible. Pool ladders will be given one finish coat of aluminum paint consisting of aluminum paste conforming to Federal Specification TT-P-320, type II, class B thinner compatible with varnish and varnish conforming to Federal Specification TT-V-119, mixed in the proportion of 2 pounds of paste to not more than 1 pint of thinner to 1 gallon of varnish. The paste, thinner, and varnish will be mixed on the job.

15-14. PAINTING PIPING.

The piping system should be marked for easy identification of lines. This can be accomplished by painting colored bands and placing markers on pipes with arrows to indicate direction of flow. The following color code is suggested:

a. Pool supply line—bright blue.
b. Filtered water return line—bright green.
c. Pool water return line—brown.
d. Chlorine line—bright yellow.
e. Backwash and sewer lines—bright red.

15-15. CHEMICAL CLEANING (DIATOMITE FILTERS).

a. Each filter manufacturer has developed cleaning methods which are considered best for their particular filter. These cleaning instructions are included in the manufacturer's operation manual provided with each filter installation; the manual should be followed carefully when the filter is cleaned. (A manual should be available at the Directorate of Engineering and Housing's office for reference.)

b. The following cleaning methods have been found successful. Filter elements in swimming pool filters can be cleaned either by removing and cleaning by hand, or by removing and soaking with a suitable chemical solution to loosen the plugging materials. Cleaning is then followed by a thorough rinsing in place. Iron oxide (rust) is best removed by inhibited hydrochloride (muriatic) acid. For elements covered by metallic cloth and those covered with most synthetic fiber filter cloths, the acid concentration should never be more than two percent. For aluminum oxide or stone elements, the concentration can be as high as five percent. If other metallic oxides (particularly manganese) or a filter aid is the main contaminant, use about one pound of anhydrous sodium bisulfite to every 50 gallons of two percent to five percent acid used.

Where dirt or organic matter is the primary plugging material, use a two percent solution of inhibited sulphuric acid, or an eight percent solution of anhydrous sodium acid sulfate in water instead of the hydrochloric acid.

NOTE

Do not use acid on nylon filter cloth.

c. The solution should be mixed and pumped into the filter. While the soaking of the metallic elements should not exceed one half hour (unless the filter manufacturer's instructions indicate longer soaking is satisfactory), stone elements may be soaked up to 3 hours. Where possible, mild agitation during the soaking period will aid cleaning. After cleaning, the filter should be drained and flushed with water. If acid has been used, rinse the filter with water followed by a solution of 0.1 pound per gallon of soda ash to neutralize any remaining acid, and follow with a final water rinse.

15-16. BACKWASHING.

Backwashing a pressure filter at too high a rate, or operating it beyond a 5-pound loss of head results in an upset or broken gravel bed. Inspecting the gravel bed of a pressure filter is difficult because sand must first be removed from the gravel. Therefore, the condition of the gravel bed usually is observed by noting whether the condition of the sand bed or anthracite coal indicates a uniform distribution of wash water. The condition can also be determined by noting whether the effluent contains sand or fine gravel. When the condition of the sand bed shows that the wash water distribution is not uniform or when sand is found in the filter effluent, complete removal and replacement of the filtering medium usually are advisable.

15-17. FILTER REPAIRS.

Damaged filter element sleeves (cloths) are easily replaced. It is advisable to have at least two replacement sleeves on hand. In the event that no replacement is available, the filter element with the damaged sleeve should be removed from the tank, the exposed manifold outlet plugged, and the filter unit returned to operation. The removed filter element will shorten the filter cleaning cycle, but operation can be maintained until a replacement sleeve becomes available.

15-18. OPERATING AND REPAIR PROCEDURE FOR CHLORINE EQUIPMENT.

Many chlorine equipment failures and chlorine leaks can be attributed to improper procedures in operation and handling of chlorine valves. This item should receive first attention in the training of pool operators who are to operate gas chlorinators. Chlorine cylinder valves are specially designed and contain a fusible metal plug. This plug is a safety device which softens and melts at temperatures of 158° F to 165° F. The valve should never be operated with other than the special wrench provided. A light bump on the wrench with the hand may be necessary to crack the valve open. Always refer to manufacturer's instructions when adjusting or otherwise maintaining chlorinators. In case of major difficulty, request that a manufacturer's representative investigate the problem.

15-19. PREVENTIVE MAINTENANCE.

Preventive maintenance services covering volumetric dry feeders, gravimetric belt-type dry feeders, loss-in-weight-type gravimetric feeders, continuous lime slakers, and other auxiliary equipment are covered in TM 5-661.

15-20. CORROSION CONTROL.

Generally, there are two types of corrosion:

a. That which acts externally on pipes buried in the soil.

b. That which, through certain liquids conveyed, acts internally on the piping. Although the damaging results are similar in both types, the methods of prevention or control differ.

15-21. CORROSION PREVENTION.

a. While it normally is possible to chemically treat fluids flowing inside pipes to minimize internal corrosion, the prevention of external pipe corrosion, resulting from certain surrounding soils, requires special consideration. Where corrosive ground conditions are known to exist, a protective coating for buried pipe or piping made of noncorrosive materials should be used.

b. Where internal corrosion of a piping system is of such nature as to require corrective action, competent advice should be obtained through qualified Facilities Engineer personnel. Likewise, similar advice should be obtained when algae and slime persist in the system. Only chemicals approved for use in potable water treatment processes are permissible and at prescribed dosages.

15-22. UNDERWATER LIGHTING.

The underwater pool lighting system will be inspected as often as required to insure safe and proper operation. Every 6 months the lighting system, including equipment grounding, will be tested with proper instruments to insure compliance with Article 680, National Electrical Code. For pools which are closed seasonally, one of the semiannual tests will be made prior to reopening of the pool. Deficiencies found will be corrected immediately.

15-23. OTHER ELECTRICAL FACILITIES.

Other electrical facilities for the pool, bathhouse, and equipment will be inspected in accordance with TM

5-681. For pools which are closed seasonally a complete inspection will be made prior to reopening of the pools. Deficiencies found will be corrected immediately.

CHAPTER 16

RECORDS

16-1. POOL CONSTRUCTION DRAWINGS.

One set of as-built drawings showing plan, elevation, all details, and general information such as construction material specifications used in the facility are to be kept on file with the Facilities Engineer.

16-2. PIPING DIAGRAMS.

One general drawing of the entire piping layout (from freshwater inlet to drainage outlet) should be posted in the equipment room for ready reference by pool operators and maintenance personnel. Pool operators should study the drawing to become thoroughly familiar with the piping system.

16-3. EQUIPMENT OPERATING INSTRUCTIONS.

Copies of manufacturer's equipment operating instruction manuals will be made available to pool operators with additional copies retained in the Facilities Engineer's office.

16-4. VALVE INDEX.

A listing of all valves and their normal status (open or closed) will be posted in the equipment room for ready reference by pool operators and maintenance personnel.

16-5. MAINTENANCE RECORDS.

Preventive maintenance services are effective only if careful, accurate, and timely records are kept of work done. These records are necessary to certify that prescribed periodic servicing of equipment is being accomplished by responsible personnel and thus insure that equipment is being properly maintained. Procedures for setting up and maintaining a preventive maintenance record card system are contained in TM 5-661. Consult equipment manufacturers' publications or the above manuals for recommended preventive maintenance intervals.

APPENDIX A

REFERENCES

1. TB MED 575, Occupational and Environmental Health Swimming Pools and Bathing Facilities, June 1982.
2. TM 5-682, Repair and Utilities Safety Electrical Facilities, October 1964.
3. TM 5-660, Operation of Water Supply and Treatment Facilities at Fixed Army Installations, August 1984.
4. TM 5-652, Steam, Hot Water and Gas Distribution Systems Repairs and Utilities, April 1947.
5. TM 5-618, Paints and Protective Coatings, June 1981.
6. TM 5-661, Water Supply Systems at Fixed Installations, September 1945.
7. TM 5-681, Repairs and Utilities Preventive Maintenance for Electrical Facilities, Latest Edition.
8. 1981 National Electrical Code, Article 680, National Fire Preventive Association (NFPA)
9. Standard Methods for the Examination of Water and Wastewater (Latest Edition)

   Source of Supply: American Public Health Association
   1015 Fifteenth Street NW
   Washington, D.C. 20005
10. FED. SPEC. TT-P-320, Pigment, Aluminum: Power and Paste for Paint, October 1977.
11. FED. SPEC. TT-V-119, Varnish, SPAR, Phenolic—Resin, June 1977.
12. MIL-P-12742C, Primer Coating: Phenolic, Water Immersible, January 1968.

APPENDIX B

CHEMICAL OPERATIONAL PARAMETERS

These guidelines set forth the suggested operational parameters for the proper chemical treatment and maintenance of swimming pool waters. Except where specifically noted, they apply to indoor and outdoor pools, in-ground, on-ground, and above-ground pools. However, some above-ground pools may require somewhat higher chlorine concentrations, more frequent superchlorination, and more brushing or manual activity to maintain the proper pool water quality because of unusual contamination or other adverse conditions.

Chemical treatment alone will not produce sanitary pool water. A filtration system in proper operational condition is also required to attain sparkling clear, polished sanitary pool water.

A. DISINFECTANT LEVELS

	MINIMUM	*IDEAL*	*MAXIMUM*	*COMMENTS*
1. Free chlorine, p/m	1.0	1.0-1.5	3.0	Note: Chlorine should be maintained at this level continually. Super chlorinate regularly. See F-#3 below.
2. Combined chlorine, p/m	0.0	0.0	0.2	If combined chlorine is too high you may have: •Sharp chlorinous odors •Eye burn •Algae growth •Bacteria growth* (*Combined chlorine is eliminated by superchlorination.)
3. Bromine, p/m	0.8	1.5	3.0	Note: Health department officials should be consulted before use.
4. Iodine, p/m	1.0	1.5	5.0 (Includes all forms)	Note: Health department officials should be consulted before use. May discolor water. Ineffective against algae.

B. CHEMICAL VALUES

1. pH	7.2	7.5	7.8	If pH is: *TOO HIGH* •Lowers chlorine effectiveness •Scale formation •Cloudy water •Increased chemical demand •Eye discomfort	*TOO LOW* •Rapid dissipa- of chlorine •Plaster/concrete etching •Eye discomfort •Corrosion of metals
2. Total alkalinity, as $CaCO_3$, p/m	80	100	200	If total alkalinity is: *TOO LOW* •pH bounce •Corrosion tendency	*TOO HIGH* •Cloudy water •Increased scaling potential •pH maintained too high

	MINIMUM	*IDEAL*	*MAXIMUM*	*COMMENTS*
3. Undissolved solids, p/m	None	None	None	If undissolved solids are: *TOO HIGH* •Filter is not working properly •Unsightly water
4. Dissolved solids, p/m	300		1500	If dissolved solids are: *TOO LOW* •Total alkalinity may be too low •Aggressive water *TOO HIGH* •Chlorine may be less effective •Scaling may occur •Freshwater should be added to reduce solids •Salty taste •Dull water •Chemical balance difficult to maintain
5. Hardness, p/m as $CaCO_3$	50	125	800	If hardness is: *TOO LOW* •Plaster or concrete etching may occur •Corrosion *TOO HIGH* •Scaling may occur •Water has bad "feel" •Short filter runs
6. Copper, p/m	None	None	0.3	If copper content is: *TOO HIGH* •Staining may occur •Water may discolor •Chlorine dissipates rapidly by decomposition •Filter may plug •May indicate pH too low, corrosion, etc.
7. Iron, p/m	None	None	0.2	If iron content is: *TOO HIGH* •Staining may occur •Water may discolor •Chlorine dissipates rapidly •Filter may plug
C. BIOLOGICAL VALUES				
1. Algae	None	None	None	If algae are observed: Superchlorinate or shock treat pool Supplement with brushing and vacuuming Maintain adequate free chlorine residual Use approved algicide according to label directions
2. Bacteria	None	None	Refer to local health code	If bacteria count exceeds Health Department requirements Superchlorinate pool and follow proper maintenance procedures Maintain proper free chlorine residual

	MINIMUM	IDEAL	MAXIMUM	COMMENTS
D. STABILIZER				
1. Cyanuric Acid	30		150: except where limited by health department requirements (often to 100 p/m)	If stabilizer: *TOO LOW* •Chlorine residual rapidly destroyed by sunlight *TOO HIGH* •May exceed health department regulations Note: Stabilizer is not needed in indoor pools
E. ALGICIDES				
1. Quaternary algaecides, p/m	1	3	5	Note: May not be permitted in public pool. Health Department officials should be consulted. Quats may be absorbed by the filter. Quats may create a chlorine demand Ineffective against some algae May cause foaming
2. Mercury-based algaecides	None	None	None	Note: Mercurials have been banned by the U.S. Environmental Protection Agency because of toxicity hazard.
3. Copper-based algaecides (nonchelated), p/m	0.1	0.2	0.3	Note: Ineffective against some algae. Health Department officials should be consulted before using. May contribute to staining.
4. Copper-based algaecides (chelated), p/m	0.1	1.0	3.0	Note: See Note #3 above.
F. REMEDIAL PRACTICES				
1. Superchlorination frequency	Monthly	When combined chlorine is 0.2 p/m or more	Weekly	Note: Some high use spas and pools may need superchlorination three times a week or more.
2. Required superchlorination chlorine, p/m	5	10	—	
3. Required shock treatment chlorine, p/m	10	—	—	
4. Flocculating frequency	—	When needed	—	Note: Floc only to maintain water clarity and supplement filtration.
G. TEMPERATURE				
1. Temperature, F	Bather preference	82	95	If temperature is: *TOO LOW* •Bather discomfort *TOO HIGH* •Excessive fuel requirement •Increased evaporation •Bather discomfort •Increased scaling potential •Increased use of chlorine

H. WATER CLARITY

	MINIMUM	*IDEAL*	*MAXIMUM*	*COMMENTS*
1. Water turbidity, Jackson Turbidity Units	0	0.5 or less	1.0	If water turbidity is: *TOO HIGH* •Chlorine level may be too low •Filtration system may be inoperative •Too turbid water may inhibit the effectiveness of lifeguards because of reduced visibility.

APPENDIX C

MEASUREMENT OF RESIDUAL CHLORINE

(N, N-DIETHYL-P-PHENYLENEDIAMINE (DPD) METHOD)

C.1 GENERAL.

The instructions for the LaMotte-Palin DPD Chlorine-pH test kit are provided below. Instructions are keyed to this kit because of its applicability to swimming pool monitoring for pH and chlorine residuals. Other kits can be utilized in lieu of this recommended kit; consult manufacturers' specific instructions as required. The installation medical authority must approve the use of other kits. The above kit can be ordered using the nomenclature in paragraph B.7. Field test kits can be used for testing other operational parameters (e.g., alkalinity). Consult manufacturers for information on these items. Generally, free available chlorine will be the only necessary chlorine test. Other methods are presented to be utilized only if necessary (e.g., when free available chlorine drops off or is nondetectable).

C.2 PROCEDURE I: FREE AVAILABLE CHLORINE, MONOCHLORAMINE, DICHLORAMINE, AND TOTAL RESIDUAL CHLORINE.

a. Free available chlorine:

(1) Rinse the test tube with the test sample, then fill to the mark.

(2) Add one DPD No. 1 rapid-dissolving tablet.

(3) Cap the test tube and shake to dissolve the tablet.

NOTE

All comparator readings should be made in direct light with a sunlight background.

(4) Immediately insert the test tube in the comparator and match the color of the sample with the color standards. Color matching should be completed within 1 minute from the addition of the DPD No. 1 tablet. This is the free available chlorine concentration of the test sample. Identify this as Reading A.

(5) Retain this test sample if the monochloramine determination is to be made.

b. Monochloramine.

(1) To the test sample from step B2a(5) above, add one DPD No. 2 tablet. Cap the test tube and shake to dissolve.

(2) Compare the resulting color with the color standards and identify this as Reading B. Any increase in color over Reading A is due to monochloramine. Thus, Reading B minus Reading A equals monchloramine content.

(3) Retain this test sample if the dichloramine determination is to be made.

c. Dichloramine and total residual chlorine:

(1) To the test sample from step B2b(3) above, add one DPD No. 3 tablet. Cap the test tube and shake to dissolve.

(2) Compare the resulting color with the color standards and identify this as Reading C. The increase in color over Reading B is due to dichloramine. Thus, Reading C minus Reading B equals dichloramine content.

(3) Reading C also represents the total residual chlorine content.

C.3 PROCEDURE II: FREE AVAILABLE CHLORINE, COMBINED CHLORINE AND TOTAL RESIDUAL CHLORINE.

a. Free available chlorine. Follow steps B2a(1) through (5) above. This is Reading A. Retain the test sample for the combined determination.

b. Combined chlorine and total residual chlorine:

(1) To the test sample from B3a above, add one DPD No. 3 tablet, cap, and shake to dissolve.

(2) Compare the resulting color to the color standards and identify this as Reading C. Any increase in color over Reading A is due to combined chlorine (monochloramine plus dichloramine). Thus, Reading C minus Reading A equals combined chlorine content.

(3) Reading C also represents the total residual chlorine content.

C.4 PROCEDURE III: TOTAL RESIDUAL CHLORINE.

The DPD No. 4 tablet provides a one-step determination for total residual chlorine and is used where it is not necessary to distinguish the separate chlorine fractions.

a. Rinse the test tube with the test sample, then fill to the mark.

b. Add one DPD No. 4 tablet, cap, and shake to dissolve.

c. Compare the resulting color with the color standards. This reading represents the total residual chlorine content.

NOTE

In situations where total residual chlorine values of more than 6.0 p/m are encountered, the test sample should be diluted with one or

two times the sample amount with chlorine free water to bring the chlorine concentration within the test range of the Octet comparator. The test result is then multiplied by the appropriate factor. For example, if one part test sample is diluted by one part chlorine-free water, the test result is multiplied by a factor of two.

C.5 PROCEDURE IV: pH TEST.

The Lamotte-Palin Phenol Red Indicator Tablet contains Halidex that eliminates the bleaching effect of chlorine or bromine on the pH indicator dye. No additional treatment is required when the halogen level is below 8.0 p/m.

a. Rinse the test tube with the sample, then fill it to the mark.

b. Add one LaMotte-Palin Phenol Red Indicator Tablet, cap, and gently shake to dissolve.

c. Immediately insert tube in comparator to obtain color match. If the test sample color is in between two standard colors, the midpoint between the two standard values is taken as the value of the sample.

C.6 PRECAUTIONS FOR USE OF TESTING EQUIPMENT.

The following suggestions are made in order to obtain the maximum performance from this equipment:

a. Follow all instructions with great care.

b. Carefully wash and rinse all apparatus used in the test procedure.

c. Tighten the reagent container caps immediately after use. Do not interchange caps.

d. Avoid prolonged exposure of all test reagents to direct sunlight.

e. Avoid extreme high temperatures and protect all test components from freezing.

f. Anticipate requirements for replacement reagents.

g. Keep the reagent containers locked up in a cabinet.

C.7 EQUIPMENT.

If new equipment kits are needed, or available equipment is not adequate, DPD chlorine residual kits should be ordered using the following information:

a. NSN 6630-027-3914, COMPARATOR, COLOR, Chlorine and pH Determination, DPD Method. Kit contains tablets for determining the presence of free chlorine, monochloramine, dichloramine, total chlorine residual and pH. Cost: $59.95. This kit may be deleted from the Federal Supply System, however, it will be available by local purchase from the LaMotte Chemical Products Co., Box 329, Chestertown, MD 21620, telephone: 301-778-3100, as Model No. LP-8, Code 6980.

b. Installation personnel must order this kit through supply procedures for ordering local purchase items. Installation procurement personnel shall handle all the local purchase administrative requirements.

c. DPD No. 1 tablets are available through the Federal Supply System (NSN 6810-01-044-0315).

d. Other reagents to refill those supplied with the kit (DPD #2, #3, #4, and pH tablets) are not available through the Federal Supply System. Installation procurement personnel should be contacted for these requests.

APPENDIX D

CALCULATION OF TURNOVER

As noted in chapter 10, the recirculation of a swimming pool is based upon turnover, or the rate at which the entire volume of the pool is theoretically recirculated through the equipment station. Initially, pool turnover is the responsibility of the designer who must insure that the mechanical system is of a sufficient capacity to handle the desired flow. As a practical matter, however, it is also desirable for the pool operator to know how the design rate is determined, for he will occasionally be called upon to evaluate the system. Since most swimming pools are required to be operated at a turnover rate of 6 to 8 hours, the operator should understand the arithmetic for computing pool volume and should be able to translate his findings in terms of flow rates.

The approximate volume in gallons of a given pool is calculated by multiplying pool length (in feet) by pool width (in feet) by average pool depth (in feet) by 7.5 as illustrated in Example 1.

EXAMPLE 1

A swimming pool 50 feet long by 20 feet wide sloping uniformly from a 3-foot depth at shallow end to an 8-foot depth at deep end.

—Area of pool (50 x 20) equals 1,000 square feet.

—Average depth $\frac{8 + 3}{2}$ equals 5.5 feet.

—Volume of pool (1,000 × 5.5) equals 5,500 cubic feet.

—Capacity of pool (5,500 cubic feet × 7.5 gallons per cubic foot) equals 41,250 gallons.

—The calculations of Example 1 make it possible to determine the pumping rate required to provide an 8 hour turnover as shown in Example 2.

EXAMPLE 2

Volume of pool in gallons equals 41,240.

—Volume (41,250) divided by turnover time (8) equals 5,156 gallons per hour.

—Gallons per hour (5,156) divided by minutes (60) equals pumping rate of 85.9 gallons per minute.

APPENDIX E

PUMP CHARACTERISTICS

(READING A PUMP PERFORMANCE CURVE)

The characteristics of a given recirculation pump are described by its performance curve. This performance curve is described best by two sets of conditions. The typical pump performance curve is expressed graphically by a chart which illustrates how much water a given pump will deliver at each of several different conditions of resistance. The amount of resistance is expressed in pounds per square inch or feet of head at the vertical line of the chart to the left in the accompanying illustration. (See figure E-1.)

The amount of flow is expressed in gallons per minute (gal/min) at the horizontal base line of the chart. This pump curve chart describes a pump which a designer might choose to recirculate the 41,000 gallon pool used for illustration in appendix D, CALCULATION OF TURNOVER.

The desired 85 gal/min would be delivered by this pump when it reaches a total system resistance of 67 feet of head. When resistance to flow is only 35 feet of head, this same pump will deliver 125 gal/min. But if resistance increases to 80 feet of head the pump will deliver only 50 gal/min, and at 90 feet of head the pump will cease moving water altogether.

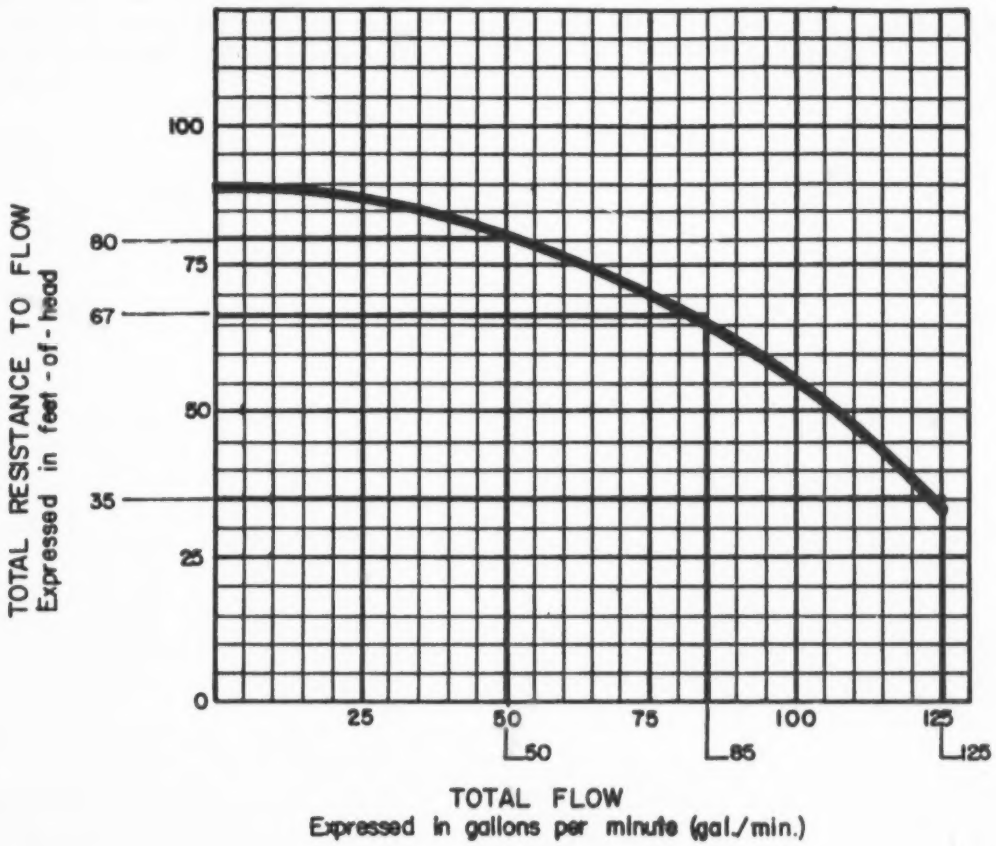


Figure E-1. Typical curve of 2 H.P. swimming pool pump

APPENDIX F

SIZING A RAPID SAND FILTER

A swimming pool containing 216,000 gallons of water, recirculated at a turnover rate of 6 hours would require a system filtration rate of 600 gal/min. The 3 gal/min/ft^2 filter flow rate as recommended in chapter 12 establishes the filter size at a total necessary area of 200 square feet. Since a standard 96-inch-diameter sand filter tank provides 50.3 square feet of cross sectional area, a four tank battery of 96-inch-diameter filter vessels would provide the exact sand surface area needed.

Carrying the example one step further, by backwashing the filter cells individually at the full circulation rate of 600 gal/min, each filter bed would receive a flow four times the rate it experiences during the filter cycle or 12 gal/min/ft^2, the approximate rate needed for effective cleaning and for satisfying public health agency requirements.

Rapid Sand Filter Sizing Calculation.

Water Volume = 216,000 gal.
Turnover Rate = 6 hrs.

$$\frac{216{,}000 \text{ gal.}}{6 \text{ hrs.}} \times \frac{1 \text{ hr.}}{60 \text{ min.}} = 600 \text{ gal/min.}$$

$$\frac{600 \text{ gal/min.}}{3 \text{ gal./min/ft. } 2} = 200 \text{ ft.}^2$$

$$\frac{200 \text{ ft. } 2}{50.3 \text{ ft. } 2/\text{filter tanks}} = 4 \text{ filter tanks}$$

Backwashing Calculation:
Circulation Rate = 600 gal/min.

$$\frac{600 \text{ gal/min.}}{50.3 \text{ ft.2/filter tank}} = 12 \frac{\text{gal/min/ft.}^2/\text{filter}}{\text{tank}}$$

APPENDIX G

SIZING A DIATOMITE FILTER

Using the example cited in appendix F, a 216,000-gallon pool operating at a 6-hour turnover would require a system flow rate of 600 gal/min. At a 2 gal/min/ft^2 filter flow rate, as recommended in chapter 13, the system would be provided with a filter having 300 square feet of septum surface area. At a 1-gallon rate the filter would have to be enclosed to provide 600 square feet of septum area. The 600 square foot filter has twice the dirt-holding capacity of the 300-square foot filter and therefore is obviously the best choice of the two. Since the diatomaceous earth filter lends well to compactness of design and large dirt-holding capacity in a relatively small space, logic favors low flow systems when diatomite filters are used.

Diatomite Filter Sizing Calculation:

Water Volume = 216,000 gal.

Turnover Rate = 6 hrs.

$$\frac{216{,}000 \text{ gal.}}{6 \text{ hrs.}} \times \frac{1 \text{ hr.}}{60 \text{ min.}} = 600 \text{ gal/min.}$$

$$\frac{600 \text{ gal/min.}}{2 \text{ gal/min/ft.2}} = 300 \text{ ft.}^2$$

GLOSSARY

ACIDITY—A term used to describe the characteristic of a substance as to its capability to give off a hydrogen ion (a proton). An acid is a proton donor. See pH for degree of acidity.

ADSORPTION—The adherence of dissolved, colloidal, or finely divided solids on the surfaces of solid bodies with which they are brought into contact.

AERATION—The bringing about of intimate contact between air and a liquid by one of the following methods: spraying the liquid in the air; bubbling air through the liquid; or by agitation of the liquid to promote surface absorption of air.

AIR AGITATION—The process of agitating sand in a rapid sand filter during the washing by injecting air under low pressure into bottom layers of the sand bed.

AIR BINDING—The clogging of a filter, pipe, or pump due to the presence of entrapped air.

ALGAE—Primitive plants, one or many celled, usually aquatic and capable of elaborating their foodstuffs by photosynthesis.

ALKALINITY—A term used to represent the content of carbonates, bicarbonates, hydroxides, and occasionally borates, silicates, and phosphates in water. It is expressed in parts per million of calcium carbonate.

APPURTENANCES—Machinery, appliances, or auxiliary structures attached to a main structure, but not considered an integral part thereof, for the purpose of enabling it to function; in water systems, the structures, devices, and appliances, other than pipe and conduit, which are used in connection with a water distribution system, such as valves, hydrants, services, corporation cocks, etc.

BACTERIA—Primitive plants, generally free of pigment, which reproduce by dividing in one, two, or three planes. They occur as single cells, groups, chains, or filaments, and do not require light for their life processes.

BLOWOFF—A controlled outlet on a pipeline, tank, or conduit used to discharge water or accumulations of material carried by the water.

CALIBRATION—The process of taking measurements or of making observations to establish the relation between two quantities.

CHLORINATION—The application of chlorine to water, generally for the purpose of disinfection, but frequently for accomplishing other biological or chemical results.

CLARIFICATION—The process of removing suspended or colloidal matter from a turbid liquid.

CLARITY—A term describing the clearness of water. The absence of suspended matter.

COAGULANT—A material which, when added to water, will combine with certain substances ordinarily present and form a precipitate comprising floc particles more or less gelatinous in character, having the capacity to remove colloids from water.

COAGULATION—

(1) The agglomeration of colloidal or finely divided suspended matter by the addition to the liquid of an appropriate chemical coagulant, by biological processes, or by other means.

(2) The process of adding a coagulant and other necessary reacting chemicals.

COLLOIDS—

(1) Finely divided solids which will not settle but may be removed by coagulation or biochemical action.

(2) In soil physics, a discrete mineral particle less than 2 micrometers in diameter.

(3) A finely divided dispersion of one material called the "dispersed phase" in another called the "dispersion medium."

CONDENSATION—The process by which a substance changes from a gaseous to a liquid or solid state or condition.

CONTAMINATION—A general term signifying the introduction into water of microorganisms, chemicals, wastes, or sewage, which render the water unfit for its intended use.

CORROSION—The gradual deterioration or destruction of a substance of material by chemical action, frequently induced by electrochemical processes, the action proceeding inward from the surface.

CRENOTHRIX—A genus of bacteria characterized by unbranched attached filaments having a gelatinous sheath in which iron is deposited. They precipitate metallic deposits in pipes, etc., which sometimes color the water. They also, after their death, cause disagreeable taste and odor in the water.

DETERGENT—A cleaning agent which acts like soap, but is more effective on grease and dirt.

DIATOMACEOUS EARTH—(DIATOMITE)—Minute, variously shaped, silica skeletons of diatoms

which were small, single cell marine plants that lived years ago. Diatomaceous earth is often used as a filter medium in swimming pool filters.

DIFFUSER—A porous plate or tube through which air is forced and divided into minute bubbles for diffusion in liquids. Commonly made of carborundum, alundum, or silica sand.

DISCHARGE—

(1) As applied to a stream, the rate of flow, or volume of water flowing in a stream at a given place and within a given period of time.

(2) The act involved in water or other liquid passing through an opening or along a conduit or channel.

DISINFECTION—The killing of the larger portion (but not necessarily all) of the harmful and objectionable microorganisms in, or on, a medium by means of chemicals, heat, ultraviolet light, etc.

EFFECTIVE SIZE—An index of grain size of a filter sand. The grain size which is smaller than 90 percent (by weight) of grains in the sand and larger than 10 percent.

EFFLUENT—A liquid which flows out of a containing space, particularly sewage, water or other liquid flowing out of reservoir, basin or treatment plant, or part thereof.

ELECTROLYSIS—A form of corrosion occurring in metallic pipe or metallic structures. It is caused by stray electric currents which pass through the earth or other conductor to the pipe, follow the pipe, and later pass again into the ground, and reach another conductor. Such corrosive action occurs where the current leaves the pipe, and metallic ions in the pipe, induced by the flow of electrical current, enter the soil at that point.

EVAPORATION—The process by which water passes from a liquid state at temperatures below the boiling point to vapor.

EXAMINATION OF WATER—

(1) Bacterial: Determination of the presence, number, and identification of bacteria.

(2) Chemical: Determination of character and composition of matter contained in the water.

(3) Microscopic: The examination of water to determine the type of plant and animal life present, such as algae, diatoms, protozoa, crustacea, etc., as an indicator of the source of the water, pollution by sewage and forms of organic life which may cause objectionable tastes, odors, or appearances, or interfere with filtration.

FILTER—A device or structure for removing solid or colloidal material, usually of a type that cannot be removed by sedimentation, from water, or other liquid.

(1) Bed: Layers of material in a filter which remove impurities from a liquid or gas that is passed through.

(2) Zeolite Filter: Filter used to soften water. Filter medium is zeolite, a substance which will remove calcium and magnesium from water, replacing them with sodium. Does not remove suspended matter from water.

FINES—The finer grained particles of a mass of soil, sand, or gravel.

FLOC—Small gelatinous masses, formed in a liquid by the addition of coagulants thereto or through biochemical processes or by agglomeration.

FLOCCULATION—The formation of floc by use of coagulating chemicals and mechanical agitation.

GAGES—

(1) Pressure gage: A device for registering the pressure of solids, liquids, or gases. It may be graduated to register pressure in any units desired.

(2) Recording gage: A gage which makes a continuous record, also called a register.

(3) Water-level gage: A gage, recording or otherwise, which indicates the water level in a reservoir, still well, or other receptacle.

HARDNESS—A characteristic water chiefly due to the existence therein of the carbonates and sulfates and occasionally the nitrates and chlorides of calcium, iron and magnesium which cause "curdling" of the water when soap is used, an increased consumption of soap, the deposition of scale in boilers, and sometimes objectionable taste in water.

IMPERVIOUS—A term applied to a material through which water cannot pass. Also applied to material through which water passes with great difficulty.

INDICATOR—A chemical which reacts with other chemicals to develop a color which can be identified.

INFILTRATION—

(1) The flow or movement of water through the interstices or pores of a soil or other porous medium.

(2) The absorption of water by the soil, either as it falls as precipitation, or from a stream flowing over the surface.

INFLUENT—Sewage, water or other liquid, raw or partly treated, flowing into a reservoir, basin, or treatment plant, or part thereof.

LEPTOSPIROSIS—An infection caused by the organism Leptospira.

MICROORGANISM—Minute organism either plant or animal invisible or barely visible to the naked eye.

MURIATIC ACID—A name for hydrochloric acid.

PATHOGENIC—Disease producing.

PERCHLORON—A chloride containing a large amount of chlorine.

PERCOLATION—

(1) The flow or trickling of a liquid downward through a contact or filtering medium. The liquid may or may not fill the pores of the medium.

(2) The movement or flow of water through the interstices or the pores of a soil or other porous medium.

PERMEABILITY—The property of a material which permits appreciable movement of water through it when saturated and actuated by hydrostatic pressure of the magnitude normally encountered in natural subsurface waters.

pH—Measure of hydrogen ion concentration, indicating degree of acidity or alkalinity of a solution. Values below 7.0 indicate acidity and above 7.0 alkalinity.

POLLUTION—The addition of sewage, industrial wastes, or other harmful or objectionable material to water.

POTABLE—Water which does not contain objectionable pollution, contamination, minerals, or infection, and is considered satisfactory for domestic consumption.

P/M—Standard abbreviation for parts per million.

PROTOZOA—Small one-celled animals including amoebae, ciliates, flagellates.

PURIFICATION—The removal by natural or artificial methods, of objectionable matter from water.

RESIDUAL (CHLORINE)—The quantity of chlorine, in excess of the chlorine demand, remaining in water, sewage, or effluents after a selected contact period of time, expressed in parts per million. The difference between the chlorine dose and the chlorine demand.

SEDIMENT—

(1) Any material carried in suspension by water, which will ultimately settle to the bottom after the water loses velocity.

(2) Fine waterborne matter deposited or accumulated in beds.

SILICA—Crystalline silicon dioxide ($Si O_2$)—Quartz.

SILT—

(1) Soil particles which constitute the physical fraction of a soil between 0.005 mm and 0.05 mm in diameter.

(2) Fine particles of earth, sand, or soil carried in suspension by flowing water. Sometimes includes material rolled along stream bed.

SLOUGH—To cast off a thin film of scum or a mass of bacterial growth or fungus.

SLUDGE—The accumulated settled solids deposited from sewage or industrial wastes, raw or treated, in tanks or basins, and containing more or less water to form a semiliquid mass.

SLURRY—A thin watery mixture.

SPALLING—A breakaway of concrete in thin layers, caused by water and thermal changes, expanding and loosening the surface layers.

STERILIZATION—The destruction of all living organisms, ordinarily through the agency of heat or of some chemical.

STRAINER, WELL—A special form of slotted or perforated well casing that admits water from an aquifer consisting of unconsolidated granular material, while preventing the granular material from entering the well.

SURGE—A momentary increase in flow (in an open conduit) or pressure (in a closed conduit) which passes longitudinally along the conduit, due usually to sudden changes in velocity.

TUBERCULATION—A condition which develops on the interior of pipelines due to corrosive materials present in the water passing through the pipe and which results in the creation of small hemispherical lumps (tubercles) on the walls of the pipe, which increase the friction loss and, by reducing the velocity, also reduces the capacity of the pipe.

TURBID—Cloudy—not clear.

TURBIDITY—

(1) A condition of a liquid due to fine visible material in suspension, which may not be of sufficient size to be seen as individual particles by the naked eye but which presents the passage of light through the liquid.

(2) A measure of fine suspended matter (usually colloidal) in liquids.

VACUUM—Condition existing in a closed space from which all gas, vapor, or other matter has been removed. Commonly applied to a closed space in which pressure is much lower than surrounding atmospheric pressure; any space where negative pressure exists.

VENTURI TUBE—A closed conduit or pipe containing a gradual contraction, which causes a reduction of pressure head, by which the velocity may be determined. The contraction is generally followed, but not necessarily so, by an enlargement to the original size.

VISCOSITY—The cohesive force existing between particles of a fluid which causes the fluid to offer resistance to a relative sliding motion between particles.

WATER HAMMER—The phenomenon of oscillations in the pressure of water in a closed conduit flowing full, which results from a too rapid acceleration or retardation of flow. Momentary pressures greatly in excess of the normal static pressure may be produced in a closed conduit from this phenomenon.

WEIR, MEASURING—Device which measures flow of water. Generally, a thin vertical plate with a rectangular, trapezoidal, triangular, or other shaped notch at the top. Depth of overflow (head) of water flowing through the notch is an index of rate of flow.

SWIMMING POOL OPERATING LOG

For use of this form, see TM 5-662; the proponent agency is USACE.

WEEKLY LOG

FROM

TO

INSTALLATION

POOL BLDG NO.

1. TYPE CHLORINATION	2. TYPE FILTERS	3. NO. OF OPERATING FILTERS	4. AREA OF FILTERS

ITEMS TO BE CHECKED	SUN	MON	TUE	WED	THU	FRI	SAT
5. CHLORINE RESIDUAL							
6. pH							
7. CHLORINE USED (lbs/hr)							
8. RECIRCULATION RATE (gpm)							
9. PUMPING TIME (minutes)							
10. TOTAL WATER RECIRCULATED (gal.)							
11. DRAINED (yes or no)							
12. VACUUMED (time)							
13. PRESSURE LOSS ON FILTER (lbs.)							
14. BACKWASHED (time-filter No)							
15. BACKWASH RATE (gpm/sq. ft)							
16. BACKWASH TIME (minutes)							
17. BACKWASH WATER USED (gal.)							
18. OTHER CHEMICALS USED (lbs.)							
19. HAIR CATCHER CLEANED (time)							
20. MAXIMUM BATHING LOAD							
21. ESTIMATE OF TOTAL BATHERS							
22. TIME POOL OPENED							
23. TIME POOL CLOSED							

24. REMARKS (Report any unusual conditions, operating difficulties, change in treatment, equipment repairs, etc.)

25. APPROVED

26. DATE

DA FORM 3164-R, DEC 85

EDITION OF AUG 66 IS OBSOLETE.

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DA FORM 3164-R, SWIMMING POOL OPERATING LOG

INSTRUCTIONS

Item

1. Type chlorination: Enter type of chlorine dosing equipment used, such as gas chlorinator or hypochlorinator.
2. Type Filters: Enter description of filters including type (gravity, pressure, or vacuum) and name of filter media (sand, anthracite, or diatomaceous earth).
3. Number of Operating Filters: Self-explanatory.
4. Area of Filters: Enter total filter area, in square feet, of all operating filters.
5. Chlorine Residual: Enter results of each chlorine residual determination expressed in parts per million to the nearest one-tenth (0.1).
6. pH: Enter pool water pH to the nearest one-tenth (0.1).
7. Chlorine Used (lbs/hr): Enter the average total weight of available chlorine used in pounds per hour during the daily operating period of the chlorination equipment.
8. Recirculation Rate (gal/min): Enter the recirculation rate as the combined actual filtration rate of all operating filters expressed in gallons per minute.
9. Pumping Time (min): Enter the total daily operating time of the recirculation pumps expressed in minutes.
10. Total Water Recirculated (gal): Enter the total daily quantity of water recirculated (pumped) expressed in gallons. This quantity should be the product of items 8 and 9.
11. Drained (Yes or No): State whether the pool was drained (emptied) during the 24-hour period.
12. Vacuumed (time): Enter the time that vacuum cleaning of the pool was performed.
13. Pressure Loss on Filter (lbs): Enter the total pressure loss in the operating filter(s), and the filter numbers, immediately prior to backwashing the filter(s), expressed in pounds per square inch (lb/in^2) gage.
14. Backwashed (Time-Filter number): Enter the time that filter(s) were backwashed and the appropriate filter numbers (filter numbers should correspond to those in item 13).
15. Backwash Rate (gal/min/ft): Enter the flow rate used in backwashing the particular filter(s) expressed in gallons per minute per square foot of effective filter area.
16. Backwash Time (min): Enter the time period, in minutes, during which the filter(s) were being backwashed.
17. Backwash Water Used (gal): Enter the total daily amount of water used to backwash filter(s). This quantity should be equal to item 15 multiplied by item 16 multiplied by the total effective filter area of the filters being backwashed.
18. Other Chemicals Used: Enter the name and quantity, in pounds per day, of all other chemicals used in the pool recirculation system, exclusive of chlorine and chlorine compounds.
19. Hair Catcher Cleaned (time): Enter the time that the hair catcher, on the recirculation system, was cleaned.
20. Maximum Bathing Load: Enter the estimated maximum number of bathers in the pool at any one time during the daily pool operating period.
21. Estimate of Total Bathers: Enter the estimated total number of bathers using the pool during the daily pool operating period.
22. Time Pool Opened: Enter the time the pool opened for use. (Express time as 1300 hrs, 1400 hrs, rather than 1:00 p.m. and 2:00 p.m.)
23. Time Pool Closed: Enter the time the pool closed, expressed as specified in item 22.
24. Remarks: Self-explanatory.

By Order of the Secretary of the Army:

JOHN A. WICKHAM, JR.
General, United States Army
Chief of Staff

Official:

MILDRED E. HEDBERG
Brigadier General, United States Army
The Adjutant General

Distribution:

To be distributed in accordance with DA Form 12-34B, Requirements for TM 5-803-10: Planning/Design of Outdoor Sports Facilities and TM 5-803-12: Outdoor Recreation Facilities.